Vol. 51 No. 2 October 1957

Quarterly

of the

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Articles and accounts of fires appearing in the Quarterly are based on material forwarded to the Association. The Association, as a body, does not assume responsibility for the accuracy of the material printed herein.

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This fire at Lajes Field in the Azores on March 11th involved a U. S. Air Force aerial tanker. The fire occurred when the landing gear collapsed during take-off. The gear failure ruptured the main right wing fuel cell. Vapors released after the spill were ignited by sparks. This fire was followed by an explosion of JP-4 fuel carried in the fuselage for aerial refueling. All eight crewmen fortunately escaped unassisted before the explosion. Two articles in this issue of the *Quarterly* are concerned with the prevention of fires of this type. See page 81 and 123.

Jet Aircraft Crash Fire Research

By I. Irving Pinkel, Solomon Weiss, G. Merritt Preston and Gerard J. Pesman

Lewis Flight Propulsion Laboratory, National Advisory Committee for Aeronautics

NACA research on the origin of crash fires, begun in 1949, has been extended to include jet aircraft. The work performed with jet aircraft follows an extensive program with piston-engine airplanes, which was reported in the NFPA *Quarterly* for October 1953. The objective of this work is to learn how turbojet crash fires start and to study means for reducing their likelihood.

Since jet airplanes have the same gross configuration and assortment of components as piston-engine airplanes, much of what was learned about the start of crash fires in piston-engine airplanes applies to the turbojet. In the jet phase of the research new elements of the problem, peculiar to the jet airplane, were emphasized. These include the jet engine, jet fuel, increased fuel quantity, and differences in fuel location. Of these new elements, the jet engine is most important. Ignition hazards presented by friction* and electrostatic sparks, electrical arcs and sparks, and air heaters remain substantially the same for piston-engine and jet airplanes. Some safety advantage is obtained from the lower volatility of jet

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Based on Technical Note 3973 issued by the National Advisory Committee for Aeronautics.

*See special article on this subject herein.

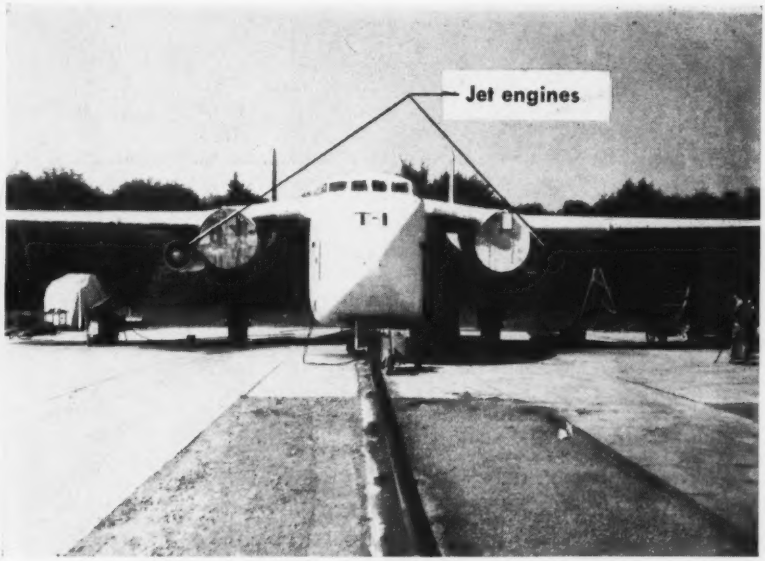

Figure 1. Modified C-82 with pylon-mounted J35 jet engine used in full scale crash tests.

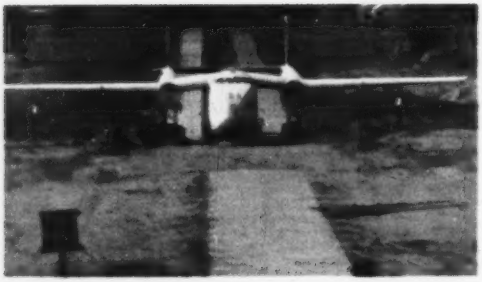

Figure 2(a). Airplane contacting barrier.

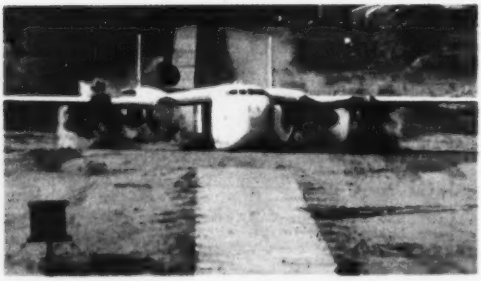

Figure 2(b). Fuel-mist cloud, 0.8 second after initial impact. (Color is dyed fuel.)

Figure 2(c). Fuel mist entering left engine (arrow), 2.5 seconds after initial impact. (Color is dyed fuel.)

Figure 2(d). Fire at engine inlet (arrow) and tailpipe of left engine, 2.6 seconds after initial impact.

Figure 2
Development of Crash Fire in Simulated Jet Bomber

(Series Continued Next Page)

Figure 2(e). Fire spread to fuel mist issuing from left wing, 2.8 seconds after initial impact.

Figure 2(f). Spread of fire 4.0 seconds after initial impact.

Figure 2 (concluded) Development of Crash Fire in Simulated Jet Bomber

fuels, but some of this advantage is counteracted by the increased quantity of fuel and its broader distribution on the airplane.

In this report interest is centered on the part the turbojet engine plays in setting crash fires. Because of the knowledge gained about combustible spillage and movement in crashes with piston-engine airplanes, this combustible spillage could be simulated for a jet engine on a test stand. Therefore, the crash-fire hazard presented by the jet engine could be assessed by test-stand studies. At appropriate times, airplanes with jet engines were crashed to verify important results obtained on the test stand.

Turbojet Crash Fires

The start of a crash fire involves three major steps: movement of the crash-spilled combustibles to an ignition source, ignition of the combustible at the source, and spread of fire to the main body of fuel on the airplane. The movement of crash-spilled fuel to ignition zones and the spread of the fire were observed in the work with piston engines and are reported in the October 1953 NFPA *Quarterly* article. There remains, then, the matter of understanding how the turbojet acts as an ignition source.

In order to observe how crash fires start with jet aircraft, two experimental full-scale crashes were conducted with turbojet aircraft having different engine installations. One of the aircraft was a C-82 airplane. The piston engines normally carried were replaced with a J35 engine pylon-mounted to each wing to simulate a bomber-type engine installation. The airplane with turbojets

Figure 3. The F-84 used in the full scale crash tests.

is shown in Figure 1. A fighter-type engine installation was represented by an F-84 airplane whose engine is submerged in its fuselage.

These crashes simulated takeoff or landing accidents, which occur at low airplane speed where the chance for human survival of the crash impact is high. In the experimental C-82 crash, turbojets accelerated the airplane from rest to a speed of about 90 miles per hour along a 1700-foot runway. A crash abutment at the end of the runway was arranged to rip off the landing gear, while a pair of poles on each side of the wing tore open the fuel tanks containing 1000 gallons of JP-4 fuel.

Simulated Jet Bomber Crash

The appearance of the airplane as it struck the barrier is shown in Figure 2(a). The cloud of fuel mist (liquid droplets suspended in air) that appeared when fuel spillage occurred while the airplane was in motion is evident at the breach in both wings (Figure 2(b)). Red dye in the fuel accounts for the bright color of the fuel cloud. As the crashed airplane slowed, the fuel mist moved forward of the wing and reached the air inlet on the left engine (Figure 2(c)). A strong cross wind swept the fuel mist away from the engine on the right wing.

Fuel mist ingested by the left engine was ignited somewhere within the engine. The ignited fuel mist produced the flames at the tailpipe and inlet shown in Figure 2(d). These exposed engine flames ignited the fuel spilling from the wing (Figure 2(e)). The flame spread through this fuel to the wing to produce the stable fire shown in Figure 2(f).

The F-84 fighter (Figure 3), carrying its turbojet submerged in the fuselage structure, caught fire in a similar crash. In this crash the fuel that entered the engine inlet was spilled from a fuselage tank adjacent to the engine-inlet duct. Arrangements for ensuring the failure of this tank in the crash are shown in Figure 4. A driving strut was attached at one end to the nose wheel strut. The free end of the driving strut carried a spear-like tank cutter aimed at the fuselage fuel tank, whose wall is adjacent to that of the air duct. When the nose wheel strut failed rearward in crash, the driving strut cut the duct and tank walls. Fuel in liquid form poured into the air duct and was drawn into the engine.

A crash of the F-84 is shown in the sequence in Figure 5. Upon passing through the crash barrier the airplane flew over a ditch toward rising ground. The fuel spilled from the damaged wing tanks in mist form and moved to the rear of the airplane (Figure 5(a)), which was traveling about 100 miles per hour.

When the nose gear collapsed on contact with the ground, the fuselage fuel tank was pierced. Fuel poured from this tank into the engine-inlet duct. Ignition of this fuel within the engine provided a succession of flame puffs issuing from the tailpipe, one of which is shown in Figure 5(b). These flame puffs moved into the wake of the airplane and continued to burn as isolated masses. Fuel spilling from the wing was ignited by these flames at the rear of the airplane (Figure 5(c)). The resulting fire moved forward through the fuel spilling from the wing and reached the slowing airplane to produce the fire shown in Figure 5(d).

The fire that occurred in these crashes of the cargo airplane with externally mounted engines and the fighter with a submerged engine showed that fuel ingested with the engine air can ignite within the engine. The flames produced may reach out of the engine tailpipe and inlet to ignite combustibles spilled around the crashed airplane.

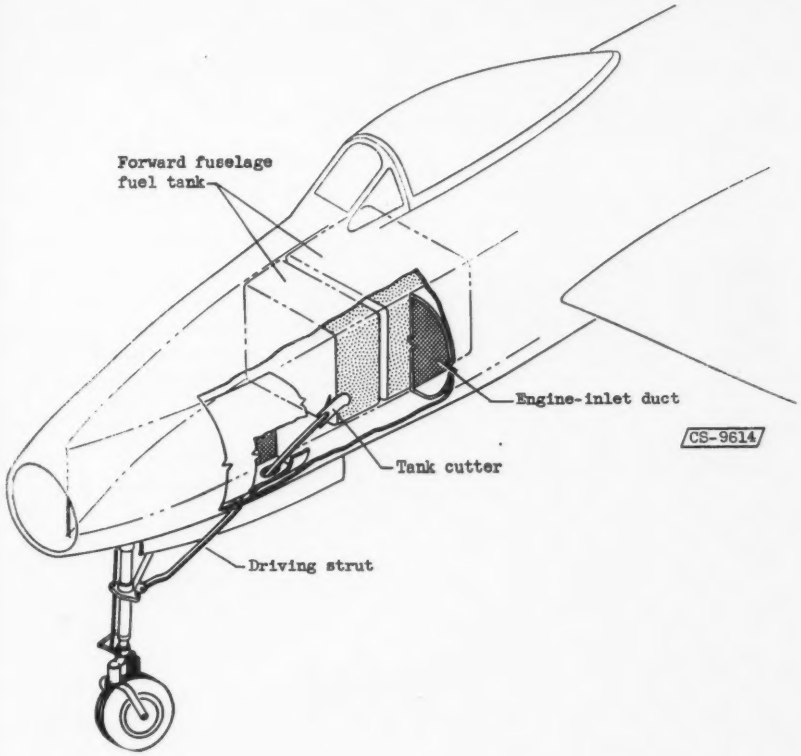

Figure 4. In the F-84 crash tests, this arrangement ensured tank failure.

Figure 5(a). Wing-tank fuel spillage, 0.35 second after initial impact. (Color is dyed fuel.)

Figure 5(b). Flames at engine tailpipe, 0.75 second after initial impact. (Dyed fuel is pink, flames yellowish.)

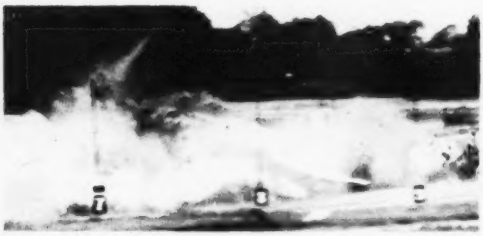

Figure 5(c). Wing-tank fuel mist, 1.10 seconds after initial impact. (Note yellowish flames at rear of fuel mist area.)

Figure 5(d). Spread of fire, 2.15 seconds after initial impact.

Figure 5
Development of Crash Fire in Jet Fighter

Role of Turbojet Engine in Crash Fires

The crash fires just described show that the turbojet plays a threefold role in setting the crash fires.

First, because the turbojet has no propeller to strike the ground and stop the engine rotation when crash occurs, the turbojet continues to operate. The large air mass flow into the engine is drawn from a broad zone ahead of the engine inlet. Combustibles spilled into this zone are sucked into the engine with this air. This ingestion of combustibles is the first step leading to the start of fire by the engine.

Second, combustibles drawn into the engine as liquid are well mixed with air by the compressor. Wetting of the compressor blades, particularly those of the rotor, promotes the evaporation of the liquid combustible in the air. Evaporation is further promoted by the heating of the air in the compressor. The ingested fuel, favorably conditioned for ignition, then moves into zones in the hot end of the engine containing combustor flame and metal above the ignition temperature of petroleum fuels, where ignition occurs.

Third, the resulting flame propagates out of the engine to spread the fire.

Even if a pylon-mounted engine is torn free in a crash, its essential role in setting fires is unchanged. The normal fuel flow to the combustor is cut off upon engine separation, but the kinetic energy stored in the rotor maintains the compressor airflow. The inlet air velocity remains high enough for about 5 seconds after combustor fuel cutoff for appreciable entrainment of spilled combustibles with the inlet air. The probability of fuel ingestion is increased when the engine tumbles into the fuel deposited under or behind the airplane.

A turbojet disintegrating in a crash could scatter hot-metal parts and burning combustor fuel into fuel-wetted areas. The resulting fire hazard is obvious and is not considered a subject for research. Experience gained in experimental crashes of turbojet aircraft in this and related programs has shown that there is little likelihood that the engine will come apart in a crash impact that is survivable. In no case did the engine break in crashes involving a total of 23 engines, yet some of these crashes produced airplane decelerations well beyond human endurance.

The characteristics of the engine as a source of ignition received the most attention in this work. Understanding the ignition process within the engine was considered the key to any useful approach to reducing this crash-fire hazard.

FUEL INGESTION

Liquid combustibles sprayed into areas of low velocity in the engine-inlet stream tube may drop to the ground before they reach the engine inlet. Liquid combustibles suspended in air (mist) entering the same zones are drawn into the inlet. Streams or jets of liquid combustibles projected into the high-velocity air within a few inlet diameters of the engine are also drawn into the inlet. As the velocity of the inlet air decreases with engine rotation, the distance at which ingestion of these streams or jets occurs shortens correspondingly.

Liquid fuel may be sucked into the engine from pools of fuel on the ground in front of the inlet. If the engine is on the ground, this fuel is drawn into the engine with the inlet air. If the engine is above the ground, a vortex that sometimes develops at the inlet and extends to the ground may raise liquid fuel from the ground into the intake airstream. Also, fuel stored in tanks adjacent to engine air-intake ducts could pour into the duct when walls separating them are breached.

Evaporation of liquid pools of fuel or fuel from wetted surfaces is a relatively slow process. This is particularly true for jet fuels with volatilities lower than aviation gasoline. Therefore, the vapors emanating from liquid fuel, spilled in the zone of influence of the inlet stream tube, rarely will

be sufficient to produce a combustible mixture with the large mass airflow into the engine. Usually, ignitable concentrations of combustibles will enter the engine only when liquids are ingested. These liquids may be in solid streams or mist form.

ENGINE IGNITION SOURCES

The two principal engine ignition sources, combustor flames and hot-metal surfaces, are sufficiently different in their behavior to merit separate discussion. These differences relate to the time these sources persist after crash, the manner in which ignition occurs, and the mode of propagation of the resulting fire out of the engine.

Combustor Flames: If normal combustor fuel flow continues after crash, the combustor flame persists as long as fuel remains in the tank. Combustibles ingested with the engine intake air are ignited immediately upon contact with this flame. Since this ingested fuel enters the combustor through air openings in its liner, which extend to the downstream end of the combustor, the burning of this fuel is not completed in the combustor. The fuel continues to burn in the tailpipe downstream of the turbine. Exposed flames that could start the crash fire might appear at the tailpipe exit, particularly if the tailpipe is short. Ignition of the ingested fuel-air mixture will occur even if it is somewhat leaner than the conventional lower combustible limit, because it is intimately mixed with the combustor flame.

If the fuel flow to the combustor is cut off by intent or accident, the main combustor flame is extinguished at once. However, the fuel manifold continues to drain slowly through the lower fuel nozzles to support small adjacent residual fires. These fires were observed in test-stand engine studies through windows in the combustor. The flames were visible up to 8 seconds after combustor fuel shutoff when the engine was operated at rated sea-level conditions. The ignition hazard provided by these residual flames compares with that of the full combustor flame. However, the ingested fuel would have to produce mixtures within the conventional combustible limits for the small residual flames to produce ignition.

Flames originating within the engine may also appear at the engine inlet as observed in Figure 2(d). The appearance of this inlet flame may be explained in the following way. Burning of ingested fuel in the combustor flame reduces the turbine-inlet gas density. A higher pressure in the combustor is required to pass the gas through the turbine. When an abrupt change in over-all combustor fuel-air ratio is provided by the ingested fuel, the pressure in the combustor required to pass the combustor gas through the turbine may exceed the capability of the compressor at the existing rotor speed. The compressor flow may stall before the turbine can accelerate the rotor to a speed that will provide the necessary pressure. At this moment the combustor flame may propagate upstream through the ingested combustible mixture that fills the stalled compressor and exit at the engine inlet.

Hot-metal surfaces: If combustor fuel shutoff is provided upon crash and residual flames are avoided, the hot engine metal may be a potential ignitor. Consequently, the temperatures of characteristic engine parts downstream of the compressor were measured on test-stand engines for a period following combustor fuel shutoff.

These temperature measurements showed that all the metal downstream of the compressor was above the laboratory measured ignition temperature of jet fuels and lubricants. These parts were at dangerous temperatures for varying periods of time after the combustor fuel was shut off. However, temperature alone is an insufficient measure of the ignition potential of a hot surface.

In contrast with flame ignition, which is instantaneous in terms of time intervals significant in this problem, ignition of combustible atmospheres by hot surfaces is not instantaneous. An appreciable contact time is required between the combustible atmosphere and the hot surface in order for ignition to occur.

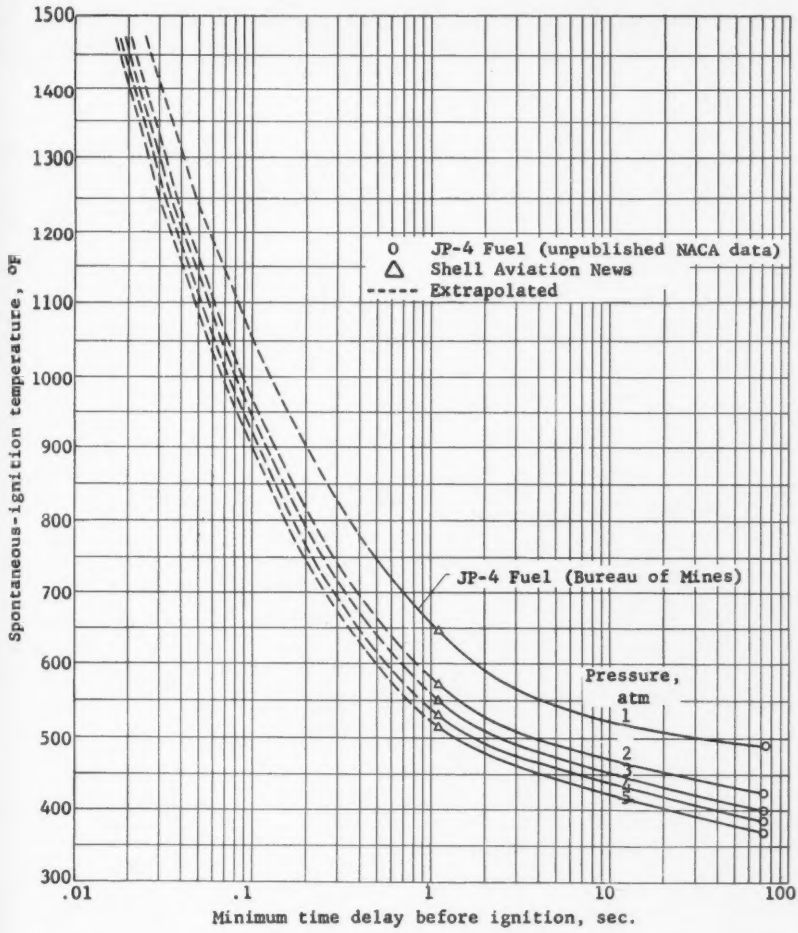

Figure 6. Ignition characteristics of JP-fuel.

The relation between surface temperature and contact time required for ignition is shown by data given in Figure 6 for JP-4 fuel. Two main trends are evident. (1) The required contact time decreases with increasing surface temperature. (2) When the combustible atmosphere is at high pressure, which exists within an engine during the initial stages of a crash, ignition is possible at a lower surface temperature for a given contact time. As the pressure decreases to atmospheric, ignition occurs at higher temperatures for a particular contact time.

The corresponding curves for kerosene and 115/145 and 100/130 aviation gasolines show the same trends as the curves for JP-4 fuel (Figure 7). The fact that a contact time of more than 0.1 second is required to ignite a combustible atmosphere of JP-4 fuel on a

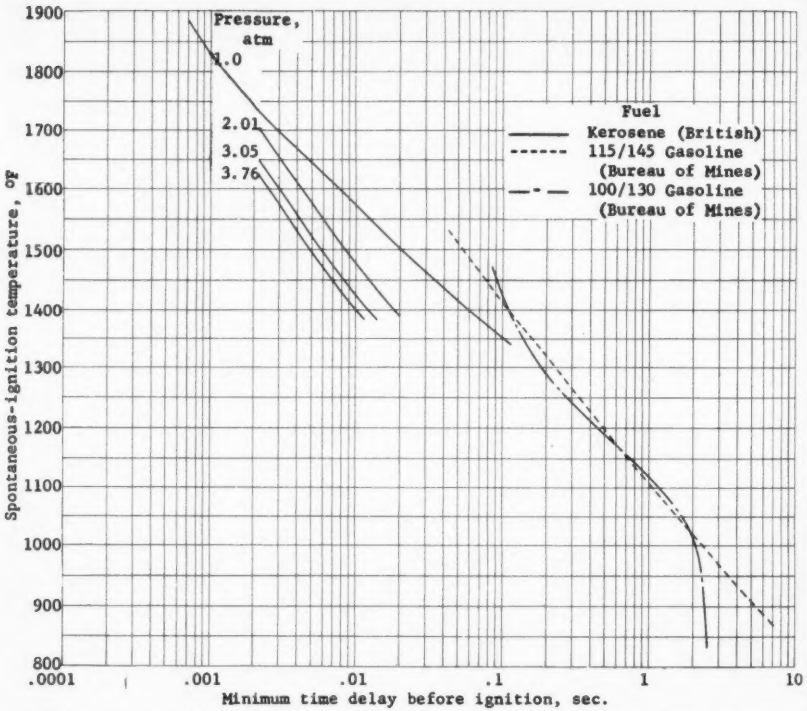

Figure 7. Ignition characteristics of kerosene and aviation gasolines.

1000° F. surface and a combustible atmosphere of gasoline on a 1400° F. surface is important in the problem being investigated.

A study of the gas velocity through the hot zones of the engine in the main gas stream showed that combustibles pass through these zones too rapidly to ignite. This is true for approximately 20 seconds following engine combustor fuel shutoff. After this period, the probability of fuel ingestion is quite low.

While the analysis showed the J30, J35, and J47 engines safe in this regard, it is conceivable that, with larger engines, ignition on the hot metal in the main gas stream may be possible. The longer components of the larger engines provide a longer transit time for the combustible atmosphere moving by. Minimum contact times for ignition may then exist for components in the main gas stream.

While ignition by hot surfaces is unlikely in the main gas streams of the engines studied, there are other zones in the engine where hot-metal ignition is likely. The hot-metal ignition zones within the engines studied were found to be in those areas where the gas velocity is less than that of the main gas stream. A small portion of the engine gas flow is diverted to hot zones in the engine where sufficient contact time for ignition exists. The quantity of gas diverted is sometimes unknown, and the geometry of the flow in the diversion zones is uncertain. For these reasons the period over which these diversion zones were hazardous was difficult to define based upon an analysis involving surface temperature and contact time.

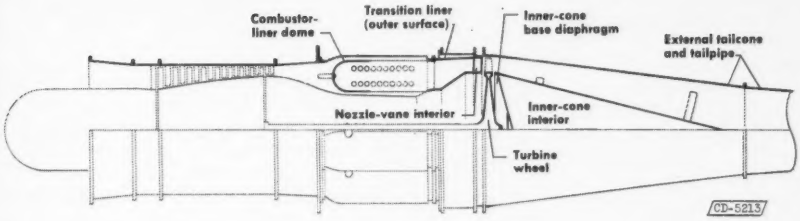

Figure 8. Hot-metal ignition zones in the J35 engine

Figure 9 (a). Tailpipe

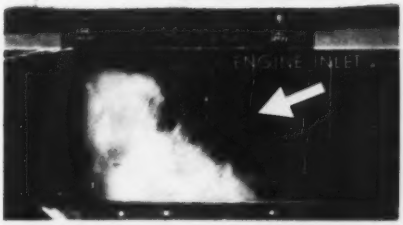

Figure 9 (b). Inlet

Figure 9. Flames issuing from engine following explosive ignition of fuel within engine

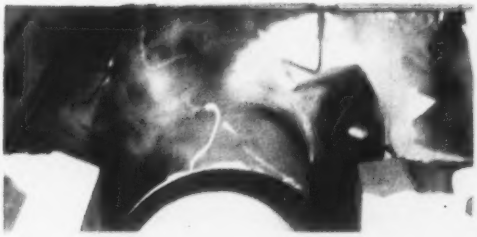

Figure 10. Fuel ignition on tailcone surface

The ignition zones were identified by the use of fuel sprays local to the engine zone suspected as an ignition source. Following engine operation at rated conditions for a time sufficient to establish temperature equilibrium, the fuel flow to the combustor was turned off and the fuel spray was turned on local to the zone under study. The fuel flow was programmed to maintain a combustible atmosphere in the zone. If ignition occurred, inerting means were installed to prevent the ignition in subsequent tests of upstream zones. By starting at the downstream end of the engine and proceeding upstream in this way, each ignition zone was identified and inerted in turn. As a final check after all the zones were inerted, fuel was injected into the main gas stream to determine whether ignition would occur. In this manner, ignition zones were found on the combustor liner, transition liner, turbine and inner-cone base diaphragm, and tailcone and tailpipe (Figure 8).

Combustor liner: The ignition zone found on the combustor liner was the dome, which lies close to the primary combustion zone. The metal adjacent to the dome is heated by the combustor flame and attains unsafe temperatures in spite of the cooling provided by the adjacent air. Also, in this region the engine air is caused to recirculate by design to provide a zone of low transitional speed and promote good combustion. Both the hot metal of the combustor liner adjacent to the dome and the residual flames previously discussed make this zone particularly hazardous. The size of this zone is difficult to define, since it depends on the air temperature at the compressor outlet, the combustor design, and the ignition characteristics of the combustibles sucked into the engine.

Transition liner: The outside surface of the transition liner, which joins the combustor to the turbine, is another ignition zone. A small quantity of air flows continuously from the combustor over the outer surface of the transition liner. Combustibles sucked into the engine inlet are brought to the outside surface of the liner with this air. In some engines this air is drawn through the hollow turbine nozzle vanes for cooling. These vanes are at the same high temperature as the transition liner and must be counted as an ignition source in this engine zone.

Turbine: The cavity containing the turbine wheel is a zone of low gas velocity. The combustibles sucked into the engine inlet are delivered to each face of the turbine wheel with the cooling air drawn from the higher compressor stages. This air moves slowly enough along the turbine wheel faces for ignition to occur.

Inner cone: Combustible atmospheres delivered to the turbine wheel from the compressor can enter the interior of the inner cone through vent holes. In some engines these vent holes are located at the base of the tailcone. The plane of the inner-cone base is parallel to the turbine wheel. Combustibles entering the cone could ignite on the hot walls of its quiescent interior. The resulting flame might ignite the combustible atmosphere streaming through the engine to produce the dangerous flames at the engine inlet and tailpipe shown in Figure 9.

Tailcone and tailpipe: The ignition zones located at the combustor dome, the outside surface of the transition liner, the hollow turbine nozzle vanes, the turbine wheel, and the inner tailcone were all that were found within these engines. Experiments showed that fires could also be obtained when fuels or lubricants contacted the outside surface of the tailcone and tailpipe. The fire produced by jet fuel on an engine tailpipe is shown in Figure 10. For engines having a pressure ratio of 5 or less, the unsafe exterior surface extends from the turbine case to the tailpipe exit.

Crash-Fire Inerting System

If fuel ingestion could be prevented, then a study of the engine ignition would not be necessary. A review of possible methods and means for employing closures at the inlet, outlet, or within the engine to prevent fuel ingestion on crash indicated little hope for this approach. Unacceptable weight and complexity were required in the closure equipment necessary to meet the

stringent specifications of fast actuation and strength to support the pressure differences developed by the compressor.

Previous crash research with piston-engine airplanes showed that a marked reduction in the crash-fire hazard could be realized by controlling potential ignition sources. Most of the ignition sources carried on the airplane are associated with the electrical system and the engine. By de-energizing the electrical system and inerting the engine ignition zones upon crash, most of the fire hazard is overcome.

The electrical system can be de-energized by opening the generator and battery circuits. The armatures of main electrical components likely to generate dangerous voltages as they coast to a stop are grounded close to these components. In this way these armatures are brought to a rapid stop, and the length of electrical wiring at dangerous voltages is shortened considerably. Ignition sources associated with the engine consist of combustor flames and hot engine metal discussed previously.

COMBUSTOR FLAMES

In a crash the combustor flame can be put out by shutting off the combustor fuel flow. Residual combustor flames can be avoided if the fuel manifold can be vented to an overboard drain at the time the main fuel vane is closed. Dribbling of fuel from the nozzles into the combustors is avoided in this way.

HOT ENGINE METAL

The problem of inerting the hot engine metal was solved during the search for these dangerous zones. The method employed for locating ignition zones within the engine involved the inerting of known ignition zones as the search for others proceeded. Water, applied to the dangerous hot surfaces, was chosen as the inerting agent, because its high heat of vaporization made possible the cooling of ignition zones with small quantities. A blanket of steam generated by the water evaporating from the hot surfaces

Table I. — Water Quantities Used for Inerting Engine Components

Internal engine components	Engine					
	J30		J35		J47	
	Water quantity, gal.	*Duration of flow, sec.*	*Water quantity, gal.*	*Duration of flow, sec.*	*Water quantity, gal.*	*Duration of flow, sec.*
Combustor domes	0.25	0.5–1.8	3	3	3	3
Transition liners and turbine-inlet vanes	0.03	0.5–1.8	1	14	1	14
Turbine wheel:						
Rapid flow			1	5	1	5
Slow flow	0.89	2.5	2	30	2	30
Inner tailcone interior	0.2	2.5	0.35	39	—	—

External engine components	Engine (airplane installation)					
	J30		J35 (F-84)		J47 Pylon installation (C-82)	
	Water quantity, gal.	*Duration of flow, sec.*	*Water quantity, gal.*	*Duration of flow, sec.*	*Water quantity, gal.*	*Duration of flow, sec.*
Tailcone Tailpipe	0.7	6	2 2.5	7 3.6	2	5
Total water required, gal	2.07		11.8		9	

inerted these zones, thus preventing ignition while the surfaces cooled to safe temperatures.

The quantities of water required to inert the separate ignition zones within the J30, J35, and J47 engines are shown in Table I. These quantities do not represent minimums but provide for a margin of safety. The water quantities listed cover all of a given class of components. For example, the 3 gallons of water for the J35 combustor include the eight combustors carried on each engine. The time duration of the water flow is given as well.

Combustor: The method of introducing the water into each J47 combustor is shown in Figure 11. A toroidal water manifold surrounded each fuel nozzle. Eight 0.082-inch holes on the downstream face of the manifold directed water at the combustor dome and its louvers leading into the combustion space. A continuous circumferential slot, 0.020-inch wide, on the perimeter of the manifold provided a sheet of water spreading radially. This water was directed downstream by the airflow to impinge and wash along the outside surfaces of the combustor liner. The 3 gallons of water delivered to the combustors of the J35 and J47 engines were divided equally among the combustors. The water discharge lasted for 3 seconds.

Transition liner: Water was delivered to each transition liner in a fan-shaped sheet from nozzles arranged as shown in Figure 12. Adequate cooling was obtained with three nozzles for each liner by directing the water at glancing incidence to the outside surfaces of the transition liner. One pint of water was discharged onto each transition liner of the J35 and J47 engines.

The water applied to the transition liner was sufficient to fill the hollow turbine-inlet guide vanes with steam for the 14 seconds the water flowed. During this period the space was inerted with steam. No additional water for the turbine vanes was required, since the main gas stream through

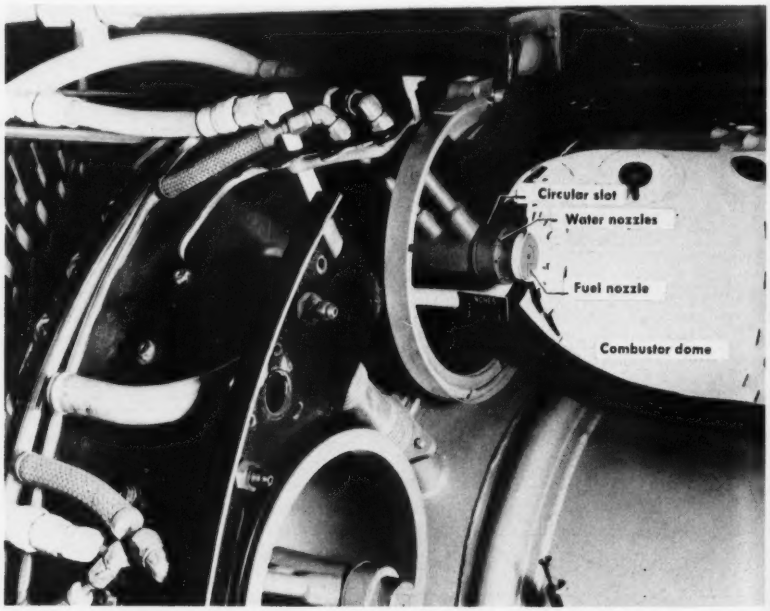

Figure 11. Combustion chamber water spray nozzle (J47 engine).

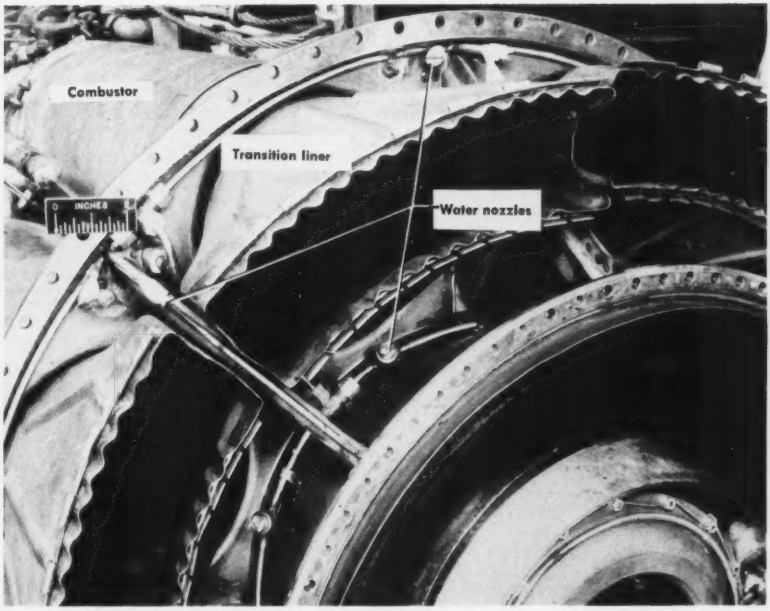

Figure 12. Transition-liner water spray system (J35 and J47 engines).

the engine cooled the vanes to safe temperature in this time.

Turbine and inner-cone base diaphragm: Cooling water to the turbine was applied as shown in Figure 13. Several streams of water issued from the water ring manifold at the hub and spread centrifugally over the rotating wheel. The J35 and J47 engines contained an inner-cone base diaphragm that was hot enough to be dangerous. Cooling was effected by discharging an additional gallon of water over a 5-second period on the downstream face of the turbine wheel through the turbine cooling air tube. A portion of this water rebounded from the spinning wheel and sprayed onto the base diaphragm.

Because the turbine wheel had large mass and thickness, reheating of the wheel surface to unsafe temperatures occurred after the applied cooling water was expended. An example of the reheating of the hottest part of the wheel is shown in Figure 14. In early experiments, when 2 gallons of water were sprayed over a 2-second period onto the aft face of the turbine at the hub, the surface temperature dropped rapidly to the boiling temperature of water (Curve A, Figure 14). Shortly after the water was expended, the surface of the wheel reheated by conduction from the hot interior. Unsafe temperatures above 600° F. were established in less than 7 seconds. In order to avoid reheating to unsafe temperatures, the water discharge period was extended to 30 seconds. Experiments indicated that the quantity of water necessary could be reduced from 2 to 1 gallon for each face of the turbine disk. The wheel temperatures obtained are shown by Curve B on Figure 14. The time interval before reheating began was increased from 3 to 20 seconds. Reheating to temperatures above 600° F. occurred after 27.5 seconds, at which time, however, the chance for fuel ingestion was remote.

This problem of reheating must always be considered in the use of water for cooling

unsafe zones. The chance for fuel ingestion by the engine is greatest just before the airplane comes to rest in the first 5 seconds after crash impact. At this time fuel spilling from torn tanks has its broadest distribution forward of the wings in areas adjacent to the engines. Reheating after this time is not as serious within the engine as it would be on the outside surfaces which could be wetted by fuel that continues to drip and flow around the engine after the airplane comes to rest.

Inner cone: The cavity of the inner cone was inerted by diluting the air with steam produced by the evaporation of water from spray nozzles within the inner cone. The initial water flow rate to the inner cone cavity should be rapid enough to reduce the oxygen concentration within the cavity below 10 per cent in 1 second. This was the approximate time latitude that existed between the start of fuel ingestion in the engine inlet and the entrance of dangerous amounts of fuel into the tailcone. The effectiveness of these arrangements was enhanced by directing the water sprays at the openings through which the fuel could enter. In this way the steam diluted the air local to the fuel entering the inner cone and

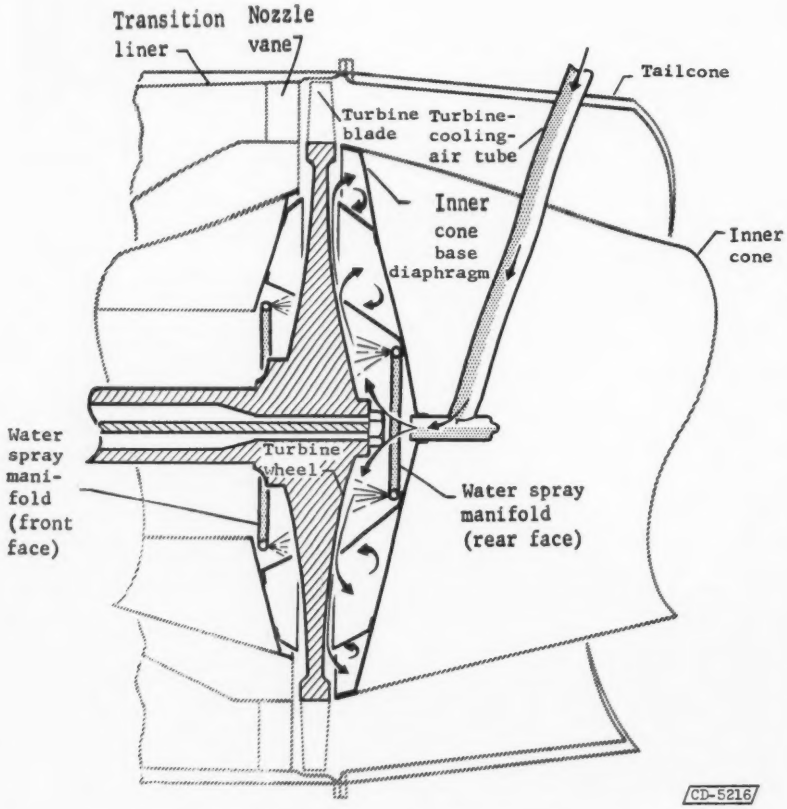

Figure 13. Schematic diagram of turbine cooling system.

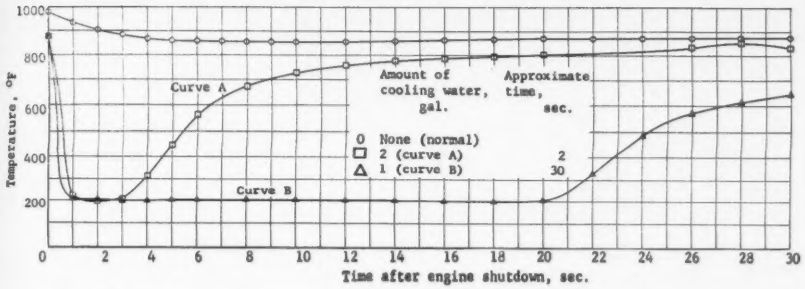

Figure 14. Comparison of turbine-wheel cooling with short (Curve A) and long (Curve B) duration water sprays. The longer duration was only 30 seconds but this time gain prevented vapor reignition temperatures being reinstated within the hazard period.

provided protection, while the steam concentration developed throughout the cavity. The chamber was maintained inert until its walls were cooled to safe temperatures by the main gas stream. For engine cavities having the low ventilation rates found in the inner tailcone, the quantity of water required for protection could be calculated from the volume of the cavity and volumes of steam generated per unit mass of water. Allowance was made, of course, for steam loss due to ventilation.

Tailcone and tailpipe: The uniform distribution and efficient utilization of the cooling water on the tailcone and tailpipe posed some problems. Because the tailcone and tailpipe were circular in section and mounted with the axis horizontal, an unduly large number of water sprays had to be used to obtain complete wetting of the outside surface. The tendency of the water sprayed on the tailpipe to form thin rivulets reduced the area wetted by each spray. Water sprayed on the tailpipe above the equator provided rivulets that ran by gravity to the equator where they dripped off. Water sprayed on the tailpipe below the equator dripped off the tailpipe a short distance from the impingement area.

Effective water distribution and wetting was promoted by wrapping a 100-mesh stainless-steel screen around the entire exhaust system. This screen was spot-welded

(Continued on page 100)

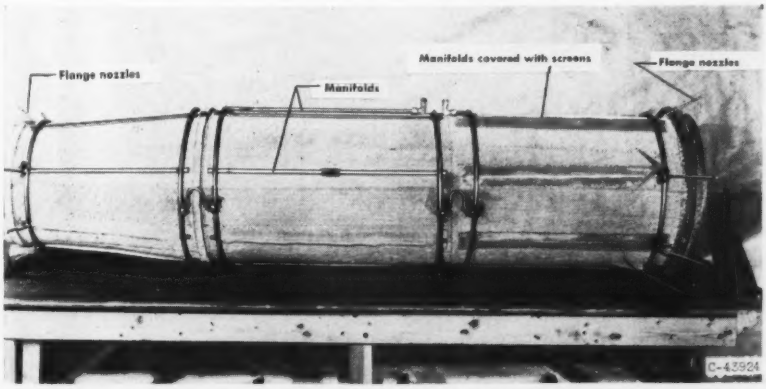

Figure 15. Typical water distribution system for F-84 tailpipe or tailcone.

Figure 16(a). Fuel mist discharging from torn wing, 0.9 second after initial impact. (Color is dyed fuel — not fire.)

Figure 16(b). Entry of fuel mist into left engine, 3.0 seconds after initial impact. (Color is dyed fuel — not fire — and the white vapor is steam from water inerting system.)

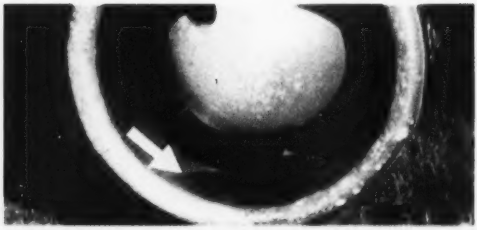

Figure 16(c). Pool of fuel left in inlet cowl indicating fuel entry into engine (see arrow). Despite this fuel, no fire occurred indicating effective inerting in the engine.

Figure 16(d). Fuel spillage on nacelle. (Note dyed section at arrow.)

Figure 16
Crash of C-82 with Jet Engines Equipped with Inerting System

Figure 17(a). 1.3 Seconds after initial impact. Pylon-mounted engine is falling free in dyed fuel mist at arrow. Plume of water vapor at tailpipe shows that the fire prevention system had been activated.

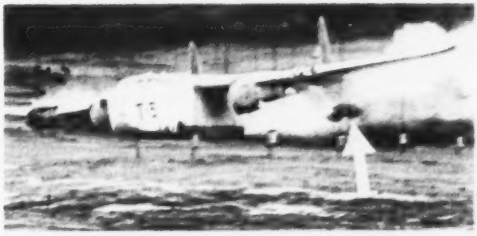

Figure 17(b). 1.8 Seconds after initial impact. Note falling engine in dyed fuel mist as indicated by arrow.

Figure 17(c). 3.1 Seconds after initial impact. Engine falling to ground in fuel mist.

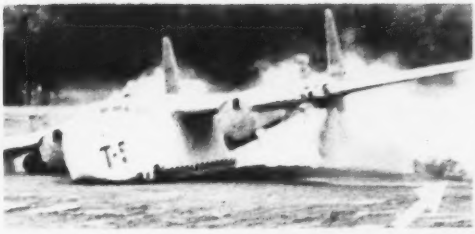

Figure 17(d). 4.4 Seconds after initial impact. Arrow indicates engine in steam vapor cloud from inerting system. No fire occurred.

Figure 17
Separation of J47 Engine from C-82 Wing in Crash

to the tailcone and tailpipe. Water sprayed on the screen penetrated to the surface of the tailpipe and tailcone. The screen promoted wetting and discouraged the formation of rivulets.

Water distribution over the screen-covered exhaust system was provided by a network of flattened tubes mounted axially in contact with the screen. Water sprayed through orifices drilled into the flattened side of the manifold facing the tailcone and tailpipe. The discharge orifices were 0.040 inch in diameter and spaced so that each would distribute water over approximately 50 square inches. Additional holes were drilled where experiment showed them to be necessary to provide uniform wetting. The tubes were also covered with ribbons of stainless-steel screen and spaced around the tailcone and tailpipe in order to provide a uniform water distribution. Three circular water manifolds connected the tubes to form a single interconnected unit. This water system is shown partially installed on the J35 tailpipe in Figure 15. Some of the flattened manifolds, which are uncovered, are visible.

Direct water sprays were provided through orifices and nozzles placed on the local circular manifolds in order to provide cooling of the massive flanges joining the tailcone to the engine and the tailpipe to the tailcone.

The quantity of water required for cooling the tailcone and tailpipe (Table I) depended upon its diameter and length and the thickness of the metal. For the J35 engine with a long tailcone and tailpipe (157 in.) sized for the F-84 airplane, 4½ gallons of water were required. Two gallons of water were required for cooling the corresponding parts in a pod-mounted nacelle with a short tailcone and tailpipe (63 in.).

The total water requirement for protecting J35 and J47 engines ranged from 9 to 12 gallons depending on the size of the tail sections. The J30 engine required approximately 2 gallons of water.

Crash Study of Inerting Systems

Two types of airplanes were used in the study of the use of water for reducing the likelihood of crash fires. Cargo airplanes (C-82) were fitted with pylon-mounted engine nacelles to simulate a jet bomber with pod-installed engines as shown in Figure 1. Fighters (F-84) were used to represent airplanes having engines submerged within their structures (Figure 3).

Installation of Crash-Fire System

The complete crash-fire protection system is comprised of a water storage and distribution system, a shutoff valve for the combustor fuel, an electric switch for de-energizing the battery and generator circuits, and a crash-actuated switch for turning on the protection system. In these tests this switch was exposed on the airplane. The switch struck a target at the crash barrier which operated the switch shortly after major airplane damage had begun. While this arrangement was suited for these experiments, more elaborate means would be required for actual airplane installations.

In order to ensure that known quantities of water were applied at each engine ignition zone, the water for each zone was carried in a separate reservoir. Compressed gas for propelling the water was contained in the reservoir. The gas space and pressure were designed to give an initial water flow rate with a subsequent decline in the flow rate that was found experimentally to provide effective use of the water. Design compromises involving reservoir location, length of water distribution lines, reservoir pressure, and required quantity of water were made in order to stay within a 0.2-second time limit (after crash impact) for the application of the water at the ignition zones. This time limit was dictated by the normal lag involved in the functioning of the hardware components of the inerting system. Considerations of rate of fuel spread in the crash indicate that it is unlikely that combustible atmospheres will contact the engine ignition zones within this short interval of time.

FULL-SCALE CRASHES

The first crash in which this inerting system was evaluated was conducted with a C-82 equipped with J47 engines. Shortly after the airplane passed through the crash barrier, the right wing tore free to produce the large volume of fuel mist shown in Figure 16(a). Entry of fuel mist into the left engine occurred 3.0 seconds after barrier impact just as the airplane began to ground-loop (Figure 16(b)). The condensed water vapor pouring from the engine tailpipe indicated that the fire-prevention system was working. The pool of fuel at the inlet lips of the left engine (shown in Figure 16(c)) represents some of the fuel that entered the engine inlet and then drained forward when the engine stopped. In spite of the fuel that entered the engines and that which poured over the nacelles (Figure 16(d)), no fire occurred. No fires occurred in two additional crashes conducted under the same circumstances.

It is evident that pylon-mounted engines on jet airplanes may part from the supporting wings in a crash. To determine whether fire protection could be provided to the engine after separation, a crash was arranged in which the left engine nacelle was torn free. The entire nacelle inerting system was built into the nacelle and designed to function regardless of the attitude assumed by the nacelle after separation from the airplane.

The airplane used in the crash in which engine separation was to occur differed from the previous airplanes only in the changes in the water reservoirs for the left engine. A blade rigidly attached to the bottom of the left nacelle was arranged to drag through an earth mound at the crash barrier and pull the engine from the wing.

Separation of the engine from the wing is shown in the picture sequence of the crash in Figure 17. After separation (Figure 17(a)) the engine tumbled in the fuel spraying into the wake of the damaged wing (Figures 17(b) and (c)) and came to rest in the fuel-wetted slide path of the airplane (Figure 17(d)). The plume of condensed water vapor at the tailpipe (Figure 17(a)) shows that the water inerting system was actuated. No fire occurred.

The crash technique for the F-84 with protected engines was identical with that used in the crash with the unprotected engine discussed in connection with Figure 5. The crash-fire protection system for the engine was the same as that for the cargo airplanes fitted with jet pods.

The sequence of events following crash were the same for the F-84 as for the cargo airplanes. Poles at the crash barrier ripped open the wing fuel tanks and produced an extensive fuel mist (Figure 18 (a)). Collapse of the nose gear allowed fuel from the torn forward fuselage tank to enter the engine inlet. Vapor issuing from the tailpipe (Figure 18 (b)) was provided in part by the fuel that passed through the engine from the damaged fuel tank adjacent to the engine inlet. Evaporation of water from the fire protection system contributed a large part of the vapors formed. Inspection of the engine after crash showed the tell-tale dye stains left by the red-dyed fuel flowing through the compressor as can be seen in Figure 19. No fire occurred.

A second crash of an F-84 airplane equipped with the fire protection system was conducted, again with no fire occurring. When the airplane came to rest beyond the crash barrier, complete wetting of the airplane by the red-dyed fuel was observed (Figure 20).

Summary of Results

A study of the ignition of combustibles sucked into the inlets of turbojet engines having a size and compression ratio of the J35, J47, and J30 engines gave the following results:

Figure 18(a). Fuel mist (at arrow), 1.1 seconds after initial impact. Fuel is dyed — no fire occurred.

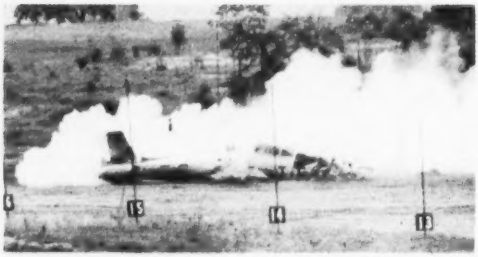

Figure 18(b). Water and fuel vapors issuing from tailpipe at aftmost location on aircraft, 3.6 seconds after initial impact.

Figure 18
Crash of F-84 with J35 Engine Inerting System Installed

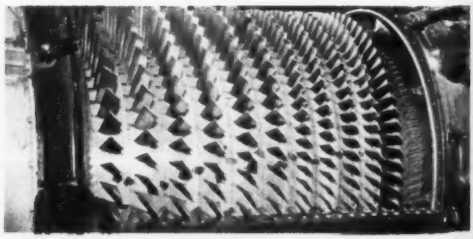

Figure 19
Fuel Dye Stains on J35 Engine Compressor following F-84 Crash

Figure 20
Extensive Fuel Wetting of F-84 following Crash with Inerting System

1. The main gas stream through the engine moves too rapidly for ignition to occur on the hot metal within the engine.

2. Ignition may occur on the hot surfaces within the engine downstream of the compressor in those zones not in the main gas stream. For the engines studied these zones include the dome of the combustor, the outside surfaces of the transition liner, both faces of the turbine wheel, the base diaphragm of the inner tailcone, and the interior of the inner tailcone.

3. Outside surfaces of the tailcone and tailpipe can ignite jet engine fuels and lubricants.

4. A crash-fire protection system which de-energizes the electrical system, shuts off the fuel flow to the engine, and sprays coolant (water) over these hot surfaces proved effective in preventing fires. Fighter aircraft with submerged engines and simulated bomber configurations with pylon-mounted nacelles were used in these studies. No fire occurred in the six crashes when the engine fire prevention system was used. Fires did occur in the two crashes in which no engine protection was provided. Coolant requirements ranged from about 9 to 12 gallons of water per engine (J35 and J47 engines) depending on the length of tailpipe to be cooled.

The Architect and Fire

By John C. Thornton, Chairman

The American Institute of Architects' Committee on Human Safety

Fires in buildings are taking the lives of our people every day. The Board of Directors of the American Institute of Architects became concerned over this high death rate and appointed the Committee on Human Safety to study the problem with instructions to first find what the architect can do in designing buildings toward saving the lives of the occupants if and when fire strikes. This study has brought to light a great many things that will aid the architect in his determination to increase life safety from fire.

In this country architects have been rather thoughtless about fire. Our heritage of wood construction may have caused us to take fire as a matter of course, rather expecting a certain amount of it and willing to take chances. We will always have fires because we have the two things that cause fire: combustible materials and people. The materials furnish the fuel and the people make the errors that touch off the fires. The architect *can* do things in design that will make fires less dangerous, but he can do very little about the people who will continue to do foolish things. What he can do, among other things, is to so design a building that when a fire does occur the occupants will not be killed by the lethal gases before they can escape.

When a great tragedy occurs the public demands new laws to prevent reoccurrence and then, in a short space of time, forgets all about it. People in general have forgotten the tragic hotel fires of ten years ago. There are, however, several organizations that are doing their best to improve our chances for a longer life. The National Fire Protection Association, the National Board

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Based on a paper presented at the 88th Annual Convention of the American Institute of Architects held in Los Angeles, California, May 22, 1956.

of Fire Underwriters, the International Association of Fire Chiefs, the National Safety Council and others are doing fine work. The American Institute of Architects has joined in this work. The difficulty is that the public, and that means most of us, has been asleep so long that it is difficult to wake us to the fact that something can be done.

"Fireproof" not Firesafe

We are trying to change the misconception that many people have that a *"fireproof" building* is a *firesafe building*. "Fireproof" does not mean firesafe. They are entirely different terms. "Fireproof" (more properly called "fire-resistive") means that the building structure will withstand a fire for a certain period time. It does not take into consideration the contents which usually consist of highly combustible fuel. A large steam boiler is fire-resistive, but we scarcely consider it safe for occupancy when burning fuel is present. It is the same with a fire-resistive building when its contents are burning. A fire-resistive building can be made firesafe more easily than a nonfire-resistive structure, but there are many things to be done on the drawing board in the early stages of design to make any building firesafe. The word *firesafe* expresses our goal.

The great killer in a fire is not the fire itself but the lethal gases of combustion which build up in an undivided and closed building, mushrooming throughout the entire structure and killing quickly, often without warning. It does not take a large fire to do this. A burning overstuffed chair or a television set can and has killed occupants in a dwelling, apartment or hotel room.

Venting

The architectural profession is making a study of fire venting in the design of buildings. Automatic vents are available and are being installed in many factory buildings as the result of a great fire in an automotive plant. We believe that they should be considered at the design stage in every building, especially where people sleep or a large number of people congregate. The problem is fairly easy in single story buildings. In multistory structures it is much more difficult and will require all the architect's ingenuity to solve. We know that it will be solved and that in a few years the installation of automatic vents will be common practice in many different types of buildings.

Venting will allow the gases of combustion to reach the out of doors by prearranged and directional control before they spread to snuff out the lives of occupants. These gases if not vented build up tremendous pressures, ready to explode under certain conditions.

We have learned that an air conditioning or a ventilating system can either be a hazard to life in case of fire or a means of venting which will save many lives. If there are no controls to stop recirculation in case of fire, gases will find their way to all sections of the building. On the other hand, a system designed to vent the floor or floors where there is fire and not allow the smoke to reach other floors could save many lives. Location of vents away from exits is important.

Vertical venting is natural and better than horizontal venting which is influenced by the wind and exposures. Venting must first be arranged to save human life and then to aid in fighting the fire.

Venting has been required for the stages of theaters as the result of tragic fires, but we have been lax in designing for it in other occupancies. In some buildings we provide drains and scuppers to drain off water to save valuable property in case of fire, but have done nothing to drain off the deadly gases to save what is far more valuable: human lives.

Many good sound-absorbing materials are not suitable for air duct linings.

Combustible linings will carry fire rapidly to all sections of a building and produce quantities of gases.

Basement Venting and Access

The design of basements is receiving more attention by architects. A high percentage of fires originate in basements and due to the contents, the gases from such fires are often highly lethal. In older buildings we had manholes for coal and ash hoists which provided means for smoke to be removed so that firemen could reach the flames. Now many basements are constructed with no openings to the out of doors and there is no way for the smoke to be drawn off except up the stairway by means of which the firemen must enter to reach the flames. Smoke from such a fire will find its way to other parts of the building. Such a situation is highly dangerous not only to the occupants but to the firemen also. We are now advocating that basements have at least one exit directly to the out of doors and also other openings for the venting of smoke on other sides if possible. There should be automatic vents for certain occupancies.

Roof Venting

Wood roofs were easy for the fireman to open to vent smoke. We also had skylights, but they are not needed where there is modern lighting and ventilation. To open a concrete roof takes valuable time and requires special tools. Every roof should have either some means for quick venting for fire department control or automatic vents similar to those used in one story buildings. We believe that for most occupancies, automatic roof vents are indicated.

Venting of Elevator and Stair Wells

Elevators should not be counted upon as exits in case of fire. Elevator doors are not smoketight and the power may fail. The shaft should be vented automatically of smoke if smoke is not to spread out on various floors.

Stair wells must not become vents for the building until all occupants have escaped. Their use, then, is the decision to be made by the fire department. We must take pains that all stair well doors fit tightly to make them as smokeproof as possible. Automatic vents at the top of stair wells are recommended by most authorities, although there is some difference of opinion on the subject. We believe that they are necessary but that there should be some means of introducing fresh air into the shaft at a low level. All exit stairs should lead directly to the out of doors. Stairways that lead to the outside through rooms that may be filled with smoke are not safe exits. Open stairways should be a thing of the past. They have caused many deaths. Last year there was a case of several deaths in a two story building because the gases went up an open stairway so quickly that the occupants did not have a chance.

The chimney effect of the open stairway was not recognized until many lives were lost. We blame past design for this condition. Let us be careful that we do not do things just as foolish and be blamed by future generations.

The present day architect is not bound by tradition as was his brother of a few years ago. If he becomes aware of hazards to life in buildings, he will find ways and means to lessen these hazards. Let us break away from the false idea that a fire-resistive building is firesafe.

Concealed Spaces

In modern design the architect is eliminating the source of many fatal fires: the inaccessible spaces containing combustible materials. Our present-day design does not require such places which were popular in the past. We are looking forward to the time when there will be few of them and when we must have them they will be of noncombustible materials. We include the drop ceilings which have been to blame for the rapid spread of many fires. Fires in these spaces often gain great headway

before discovery. The dropping of the ceiling has been known to be the first indication that there was a fire. This was called to the attention of the profession last year. There was a case of such a fire a few weeks ago and several lives were lost.

Fire Door Design

Fire doors that do not operate fail in their purpose and give a wrong sense of security. It can be said that this is usually caused by poor housekeeping. The architect can, however, design doorways so that materials piled near them will not interfere with the operation of the doors and he can check to see that the fusible links are in the line of possible fire so that they will operate when needed.

Inner Courts and Special Hazards

The question of inner courts is being studied. They should be accessible to the fire department for fire fighting, but more important for rescue. They have been listed as the cause of the rapid spread of many fires.

One of the things that the architect can do in the early stages of design is to locate certain rooms so that their location will not be a hazard to occupants of the building and at the same time provide easy access to them for the fire department. Passing a hazardous room to reach an exit is dangerous. Such rooms as pin refinishing rooms in bowling alleys, storerooms and shops in hotels and other buildings, and the operating rooms in hospitals must receive special attention as to location.

Home Fire Safety

More people die from fire in homes than in any other occupancy. We believe that automatic venting is vital in the modern home. We are building homes so tight today that we are increasing the chance of gases endangering the lives of the occupants. We are making a study of automatic venting for homes. Exits from basement recreation rooms should be directly to the out of doors. Many people have died because of open stairways in dwellings. A closed door can save lives. Doors to segregate sleeping areas are particularly important. In homes, a careful selection of building materials plays an important part in safety.

Few people realize that heating of wood and similar materials is cumulative. Wood when subjected to temperatures of a low order (steam pipes) may ignite spontaneously following the formation of porous carbon or charcoal on the exposed surface. This is why it is advisable to keep steam pipes from contact with wood.

In the proper selection of materials, the architect can be of great service to his client. The flame spread ratings of the materials should be considered. Some types of wallboards will carry fire more quickly than wood. Drapes vary from fire resistant to those that cause flash fires. Finishes may retard fire or cause it to spread rapidly. There are materials that are put on the market in two forms, flameproofed for locations where the Codes require such treatment and the same material untreated where there are no applicable Codes. We don't need laws to exercise good judgment. It should be kept in mind that flameproofing treatments for such materials as drapes are usually not permanent. Clients should be warned about the need for periodic treatments and should not be led to believe that flameproofed materials are noncombustible but that their great value is their ability to resist fire in the early stages.

Many manufacturers are trying to put out safe materials, but we will always have with us those who are willing to take chances with the lives of others. Most plastics are no more dangerous than other materials commonly used in the home but those in the pyroxylin class can be. An architect should check the flame spread of materials and for lethal gases given off when burning.

The Architect and Panic

Panic is the cause of death in many fires. While it probably is not possible to wholly eliminate panic, the architect often has the key to the conditions that cause it and can do as much as any other person to lessen this hazard. In panic, human beings become like animals. They no longer think; their only idea being flight with no thought for the safety of others. Discipline such as received in the army or during fire drills will often prevent panic, but most of our people have not had this training or have forgotten it and revert to the animal instinct. The architect can, however, design buildings to cut down the chances of it happening. He can design to give a sense of security. Exits must not only be adequate but, what is more important, must give the feeling that exit is easy. They must be well lighted and plainly marked. As people in panic most often attempt to leave by the door they entered, it is essential that these doors be more than ample and very easy of egress. Entrance doors that open in only, with no hardware on the inside, such as are often found in super markets, invite panic. The dangers of such conditions must not wait until a catastrophe causes the public to demand greater safety.

If occupants feel that it is easy to get out of a building, know that there is little combustible material present, or can see sprinkler heads, there is less danger of panic. Also, if there are automatic vents for smoke and the ventilating system does not recirculate the air in case of fire, the chances of panic will be reduced. The architect, by thoughtful design, can contribute a great deal to the sense of security.

Back to the Drawing Board

The place to study fire safety is on the architect's drawing board, not after the building is completed. The principles of the action of fire, and its fast growing children, the gases of combustion, have not changed. We also know how human beings usually act in panic. The trouble is that most people have ignored these principles. Codes which are usually minimum requirements cannot cover every kind of design adequately. It often takes a major catastrophe to bring about a demand that codes be changed. The architect must think beyond the codes as he designs, foresee what will happen in case of fire in the building he is creating and how the occupants will act. In this way he can do more to protect the lives of human beings in case of fire than any other person because he is at the seat of the fire first, before the fire occurs, while the building is being created on paper.

Meeting of Board of Directors

Boston, July 1, 1957

Present

Richard E. Vernor, Chairman
John A. Neale, President
Henry G. Thomas, Vice President
Allen L. Cobb, Past President
T. Seddon Duke, Past President
Hovey T. Freeman, Secretary-Treasurer

Dale K. Auck	Clarence W. Higbee
Warren J. Baker	Leonard Peterson
Malcolm S. Blake	J. Sharp Queener
Charles H. Bunn, Jr.	Elmer F. Reske
E. Kenneth Clark	Leigh R. Sanford
W. H. Forristall	

Percy Bugbee, General Manager; Robert S. Moulton, Technical Secretary; Horatio Bond, Chief Engineer; Charles S. Morgan, Assistant General Manager; George H. Tryon, Assistant Technical Secretary; A. L. Brown, Chairman, Committee on Technical Committee Procedure; Merwin Brandon, Chairman, Electrical Section; W. S. Marsh, Chairman, Committee on Dry Chemical Extinguishing Systems (present during part of meeting).

Business Transacted

1. The following officers were elected in accordance with the recommendation of the annual meeting: President — John A. Neale, Vice President — Henry G. Thomas, Vice President — Loren S. Bush, Secretary-Treasurer — Hovey T. Freeman, Chairman, Board of Directors — Richard E. Vernor.

2. The Advisory Committee for 1957–58 was appointed as follows: Richard E. Vernor, Chairman, John A. Neale, Henry G. Thomas, Loren S. Bush, Hovey T. Freeman.

3. Messrs. Dale K. Auck of Chicago and A. Leslie Ham of Montreal were appointed to complete the Nominating Committee 1958.

4. The 1958 annual meeting in Chicago was discussed and various suggestions made. Mr. Bugbee reported the following tentative dates for future meetings: Atlantic City — May 25–29, 1959; Montreal — May 16–20, 1960; Detroit — May 14–18, 1961; Philadelphia — May 15–19, 1962. Mr. Bugbee raised a question as to whether another meeting should be held on the West Coast in 1963. This matter was referred to the Advisory Committee for investigation and report at the next meeting of the Board.

5. The Program Committee for 1958 was appointed as follows: the President, Chairman of the Board, and the General Manager. Mr. Elmer Reske of Chicago was appointed Chairman of the committee on local arrangements and Mrs. Reske, Chairman of the Ladies' Committee.

Fall Conference — November 1957

6. Mr. Moulton reported on the fall conference to be held at the John Marshall Hotel in Richmond, Va., November 18–20, 1957, with Chief Fire Marshal C. S. Mullen, Jr. of Virginia as Chairman, and Mr. Walter Randlett of the Virginia Electric and Power Company as Vice Chairman. Mr. Moulton also reported on plans for committee meetings and other details of the meeting. There was general discussion of the conference with expressions of opinion as to the value of such meetings. In response to a question, the following Board members indicated their intention to be present at the Richmond meeting: Warren J. Baker, Malcolm S. Blake, T. S. Duke, Hovey T. Freeman, John A. Neale, Elmer F. Reske and Henry G. Thomas.

7. Treasurer Hovey T. Freeman presented his report on financial conditions. This report was approved.

8. The Budget as prepared by the General Manager and amended by the Finance Committee was approved.

Field Service Projects and Sections

9. a. Mr. Merwin Brandon, Chairman, reported on the activities of the

electrical field service. During his report he referred to the provisions in the National Electrical Code on holders for plug fuses of 30 amperes or less capacity and the action of the NFPA Board of Directors voted on July 15, 1946 to suspend the application of Par. 2452 of the National Electrical Code pending further investigation and action by the Board or by the Association. It was voted to refer this matter to the Electrical Correlating Committee for processing in the next edition of the National Electrical Code. During the discussion it was indicated that the patent situation which had complicated previous NFPA action was being resolved by the expiration of the patented time lag feature which had been a stumbling block in the adoption of the Type S fuse.

b. Mr. C. H. Bunn, Jr. reported for the Flammable Liquids Field Service indicating general satisfaction with the activities of the Flammable Liquids Engineer, Miles E. Woodworth. He said that the budget had been increased to cover rising costs and that the American Petroleum Institute would contribute its share of the increase.

c. Mr. Moulton reported for the Gases Field Service Project indicating satisfaction with the services rendered by the Gases Field Engineer, Clark F. Jones. He referred to some difficulties which had been involved in the financing of this project indicating that these had now been largely resolved.

10. Mr. Charles S. Morgan, Executive Secretary of the Fire Marshals' Section, reported on the activities of the section. He indicated the current plan to provide representation on NFPA committees with assurances given by the various fire marshals of their ability to attend meetings. He also reported action by the Executive Committee of the Section to rescind Standard No. 103, Guide for Hotel Fire Safety Law, a document developed by a special committee of the Section and adopted in 1948. It was found that the information in this guide now conflicts in some details with the Building Exits Code and it was the feeling of the Executive Committee of the Section that the Building Exits Code will suffice without the separate guide. It was accordingly voted to rescind No. 103.

11. Mr. Elmer Reske, Past President, reported on the Society of Fire Protection Engineers, indicating a healthy financial condition and a present membership of over 1,000.

12. A proposal for the establishment of junior memberships presented by the Illinois Inspection Bureau to the last meeting of the Board was discussed and it was voted to take no present action on this in view of the practical difficulty in servicing a special class of membership which did not promise to be at all numerous.

Foam Rubber Products

13. Mr. Tryon reported on the spontaneous ignition of foam rubber products and it was voted to endorse the following NFPA staff statement of Association policy:

1. That the manufacturers of products containing foam rubber tag their products with the following warning: "DO NOT DRY IN DRIERS OR OVER HEATERS" wherever such tagging would be practical — such as on small pillows, toys, ironing board pads and similar consumer products.

2. That the manufacturers of currently available types of driers publish warnings in their instruction manuals advising the public: "DO NOT DRY FOAM RUBBER PRODUCTS IN THIS DRIER."

3. That laundries and dry cleaning establishments institute an inspection program to remove foam rubber products from materials offered for processing.

4. That the public be alerted by all interested agencies to the spontaneous heating hazards of foam rubber products after they have been subjected to forced drying in home or commercial driers and

not adequately cooled and after repeated commercial dry cleaning operations. It is recommended that articles containing foam rubber be dried separately by natural means (excluding the use of driers or heaters) after washing, that the foam rubber padding be removed from the garment prior to washing or dry cleaning, or that the foam rubber padding be removed and only the covers of cotton, nylon or similar fabrics be subjected to cleaning.

Technical Committee Actions

14. A communication from Mr. C. F. Graham Reeves of the Falcon Alarm Company relative to gas pressure operated fire alarm signaling devices and systems was reviewed, also a communication on the same subject from Mr. Boyd Hartley, Chairman of the Committee on Signaling Systems and Thermostats. The entire matter was referred to the Technical Advisory Committee for consideration and report to the Board at its next meeting.

15. On recommendation of Mr. Elmer Reske, Chairman of the Committee on Garages, and in conformity with the action taken by the Association at its 1957 annual meeting, it was voted to make the following changes in the Standard for Garages, NFPA No. 88, edition of 1957:

Par. 3, last sentence, revise to read as follows:

"Any equipment containing a potential source of ignition should have the combustion chamber, ash pit, etc., raised above the floor level."

Par. 2512, insert the words "and piping" after "The dispensing unit."

Add the following sentence to Par. 2513:

"The ventilating system shall be electrically interlocked with the gasoline dispensing units so that the dispensing units cannot be operated unless the ventilating fan motors are energized."

16. On recommendation of Mr. W. S. Marsh, Chairman of the Committee on Dry Chemical Extinguishing Systems, and in accordance with the action of the 1957 annual meeting, it was voted to make the following changes in the Standard on Dry Chemical Extinguishing Systems, NFPA No. 17:

Revise the first paragraph of the Appendix to read as follows:

"The following Appendix material describes the design data and calculation procedure used for the evaluation of the "Ansul" PS-150, PS-300 and PS-500 Piped Systems. It is included for two purposes; first, as an example of the type of information which must be made available for the evaluation of a dry chemical system and secondly, as a means of evaluating the above systems. Since the flow characteristics of a dry chemical system are dependent upon the composition and physical properties of the dry chemical and the design of the equipment, this design and calculation information is applicable only to the above systems."

Delete the name "Ansul" from the text and from the illustrations throughout the balance of the Appendix.

Mr. Marsh in presenting his report indicated that all members of his committee concurred in these recommendations except one not voting. This action included a reconsideration of Par. 3121 which had been questioned in the discussion at the annual meeting.

17. Chairman A. L. Brown presented the report of the Technical Advisory Committee which was adopted including action on the following:

It was voted to create a new Committee on Fire Department Organization with a scope statement to indicate that the committee has jurisdiction over standards and recommendations for public fire department organization and operation.

It was voted to create a new Committee on Water Cooling Towers and to appoint Mr. L. A. Dutton as Chairman of this committee, with other representatives selected from the present membership of the Committee on Build-

ing Construction and from various other interests concerned.

It was voted to approve the policy of the Committee on Signaling Systems and Thermostats to subdivide its activities into various sectional committees dealing with different phases of the subject. It was also voted that the committee be authorized to proceed with the development of material on radio signaling within fire departments as a necessary adjunct to subjects now covered.

It was voted to accept the resignation of Mr. K. W. Adkins from the chairmanship of the Committee on Automatic Sprinklers, a position he has held since 1942. It was also voted to express to Mr. Adkins the appreciation of the Board for his long-continued and devoted service. Mr. Gordon F. Price of the South-Eastern Underwriters Association was appointed to the chairmanship of the committee to take the place of Mr. Adkins who, however, will remain on the committee as a personal member.

Mr. Brown also reported consideration of the question of when a committee report should be developed in the form of a law or ordinance and when a standard is sufficient. The committee was not as yet prepared to report on this but would do so at the next meeting of the Board.

18. All committee appointments contained on the list submitted with the Board agenda were approved, also appointments on a supplementary list submitted at the Board meeting. It was voted to authorize the Technical Advisory Committee to make additional appointments prior to the printing of the 1957 Year Book, subject to confirmation by the Board at its next meeting. It was also voted to reappoint all present members of NFPA committees except those who have resigned or who have been dropped in accordance with the provisions of the Regulations on Technical Committee Procedure pertaining to the degree of participation in committee work. The complete list of all NFPA committee personnel will be published in the 1957 Year Book.

19. The Technical Advisory Committee for 1957–58 was appointed by Chairman Vernor as follows: T. Seddon Duke, Chairman, A. L. Brown, Hylton R. Brown, John A. Neale, Henry G. Thomas.

Other Business

20. It was voted to hold the next meeting of the Board at the Union League Club, New York, on January 23, 1958.

21. A communication from the American Standards Association requesting the nomination of a representative of the NFPA for election to the ASA Board of Directors was referred to the Advisory Committee with power.

22. Mr. Bond reported on fire research, making reference to various activities in this field and to the publication of the NFPA book on the subject.

Mr. Cobb referred to a law suit in which he had recently been involved where the NFPA Handbook of Fire Protection was introduced as evidence.

Mr. Tryon referred to cooperation with the Boston Better Business Bureau indicating the preparation by the Better Business Bureau of a brochure dealing with home fire safety and making special reference to extinguishers of various types. Mr. Tryon reported that this text was satisfactory to the NFPA and reported plans to distribute copies to NFPA members.

Mr. Tryon reported on his participation as technical advisor to the U. S. delegate in a meeting of the International Civil Aviation Organization on the subject of fire protection at airports.

Lessons from a Pyrophoricity Incident

By Merril Eisenbud, Manager

United States Atomic Energy Commission, New York Operations Office

EDITOR'S NOTE: On July 2, 1956 a lump of cakey thorium powder exploded in the metallurgical laboratory of Sylvania Electric Company's nuclear division at Bayside (New York City), N. Y. Near-hysteria developed in the thickly populated area over the feared "radiation hazard" from the explosion and while this feat proved entirely groundless, the incident emphasized the need of preparing the public to accept nuclear risk situations. Mr. Eisenbud discusses some of the lessons learned from this accident in an interview with a reporter from NUCLEONICS magazine.

Mr. Eisenbud, do you consider the laboratory accident at Bayside to have been a serious break in the Atomic Energy Commission's remarkable safety record?

The Atomic Energy Commission is proud of its safety record. Any accident that results in the injury of people or in the death of a man is a serious break in our performance in this respect. On the other hand, I think one ought to note that this was not an accident of the type about which the AEC and the public has been mostly concerned — namely, an accident that might result in exposure of people to radiation, and in the contamination of areas with fissionable materials or fission products. This accident involved thorium, which is a slightly radioactive material, but the character of the accident was largely that of a chemical accident.

What exactly did occur at Bayside?

For some time the laboratory had been engaged in work involving finely divided thorium, as a metallic powder. Many metals, when they exist in finely divided form, are pyrophoric. It is customary, prior to ultimate disposal, to oxidize these powders under controlled conditions so that one ends up with an inert oxide rather than the original pyrophoric material. This operation is performed in an enclosure. It's a very simple operation; literally the burning of the powder at a very slow rate.

On this occasion, for a reason that we don't quite understand, there was a sudden explosion of a lump of finely divided thorium about the size of a golf ball. It's possible that the explosion was caused by impurities in the thorium. In any case we are not exactly sure what it was about this material that was different from that which had been successfully oxidized many times previously.

There was a chain of three explosions. The original material exploded in a dry box provided for this operation. This detonation resulted in the explosion of about 40 pounds of powdered thorium stored in the same room in which the operation was taking place. Then there was a third explosion that may have involved dust distributed throughout the ventilation system, or may have included other powdered metals stored in various places in that particular department. All these explosions took place within a few seconds of each other. Four men were seriously injured; one ultimately died of approximately 60 per cent third-degree burns. The explosion was severe but there was no fire. About $25,000 damage was done to AEC equipment and building; the contractor lost over $100,000.

How do the risks inherent in this type of operation compare in severity with the risks in other types of nuclear energy activities, such as reactor operations?

In the nuclear energy industry generally, you cover the entire spectrum of risk. Many

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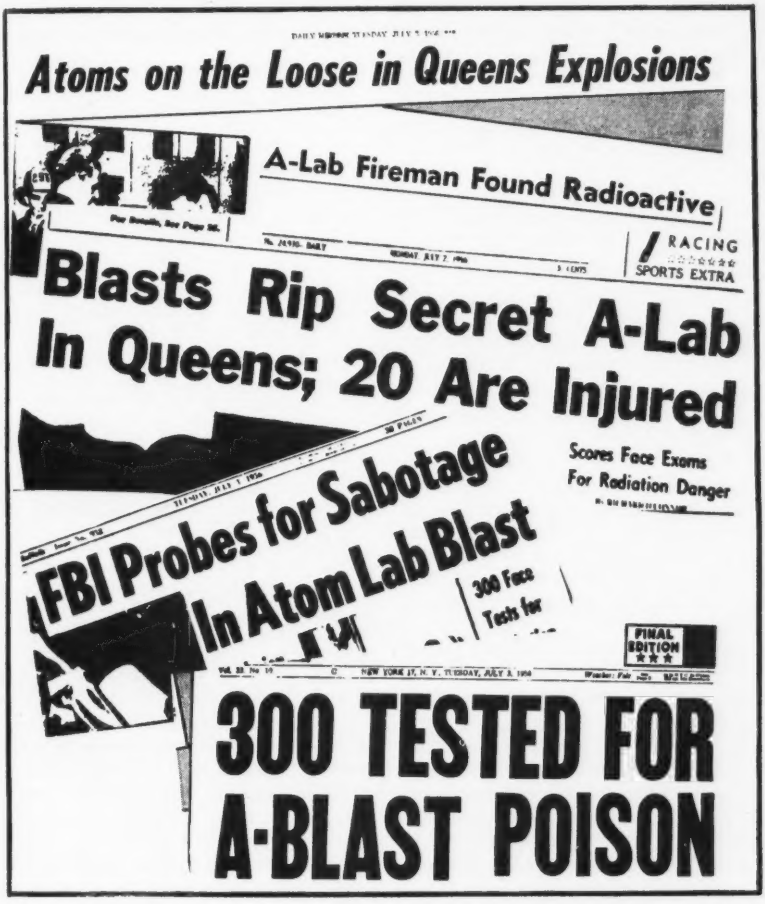
Atoms on the Loose in Queens Explosions
A-Lab Fireman Found Radioactive
RACING
SPORTS EXTRA
Blasts Rip Secret A-Lab In Queens; 20 Are Injured
Scores Face Exams For Radiation Danger
FBI Probes for Sabotage In Atom Lab Blast
300 Face Tests for
FINAL EDITION
300 TESTED FOR A-BLAST POISON

Typical scare headlines in local New York newspapers following the explosion of July 2, 1956 at the Sylvania Laboratories in Bayside, Queens County, New York.

of the things we do in atomic energy installations do not involve radioactive materials at all. They involve all sorts of mechanical and chemical procedures that are provided in support of nuclear activities. At the other end of the spectrum, of course, you have a large power reactor, or perhaps a chemical separations plant in which there is a very large potential for the release of radioactivity. As you imply, the potential risk in this particular operation was very much less than what we would have to consider when large amounts of radioactive materials were being handled, or where a large reactor was being operated.

Such large-scale operations would, under AEC's safeguard procedures, presumably be much less likely to be located near a large population center as was the case here, would it not?

As our knowledge in the reactor field increases, more and more reactors will be placed closer and closer to centers of popula-

tion. Already certain research reactors are being constructed in population centers. The development of the atomic energy industry depends on our ability to learn how to construct reactors in population centers with the same degree of assurance with which we now construct conventional power plants in those centers.

How successful was advance planning for a contingency such as the Bayside incident?

This has to be discussed from two points of view: first, the advance planning that goes into a plant emergency plan *per se*, and second, the advance planning that contemplates the problems arising out of community reactions.

PLANT EMERGENCY PLAN

The plant emergency plan generally worked well. The proper agencies — Atomic Energy Commission, fire department, police, and so on — were notified immediately; there was immediate evacuation of employees from the affected area, and there were local rescue operations and first-aid procedures that we believe were adequate to take care of the emergency as it then existed.

NEED TO ASSEMBLE EMPLOYEES

There was one serious shortcoming in the plant emergency procedure which I think may be true of a great many emergency procedures and may be worth taking note of. There was adequate provision for evacuation of the employees, but there was no plan to assemble them and keep them grouped until they could be briefed on what had actually taken place.

When the employees were evacuated from the laboratory, they were free to roam about the neighborhood. Obviously they could only speculate on what had happened, and their speculations to the policeman on the beat, the neighbors, and members of their own families, in all probability became the sources of many of the unfounded rumors that began to spread through the plant area.

I think it would therefore be important in any disaster plan to assemble the employees long enough to brief them on just what did happen, so that they can give more reliable information than that based on their speculations in the absence of good information.

PROBLEM OF COPING WITH INVESTIGATORS

There's another aspect of a plant disaster plan that is very difficult to deal with, particularly in the case of a small plant. This has to do with the large number of people who descend to the scene of emergency, for various reasons. Within a few minutes of the Bayside accident, the fire department, police department, a press corps, the health department, the state labor department, the AEC, the FBI, local civil defense officials, and the U. S. Army all sent representatives to the scene of the emergency. It is obviously not feasible for any relatively small organization as existed in this case at Bayside to deal efficiently with so many people all wanting information at the same time.

COMMUNITY EDUCATIONAL PROGRAM

As regards the community reaction, I think we learned a great deal. No educational program had been undertaken in this community, and perhaps this was shortsighted. On the other hand, neither the contractor involved nor the AEC had any reason to believe, prior to the incident, that near-hysteria would develop from an accident of this kind.

How effective was the work and the cooperation of the various agencies at the scene of the accident?

To the outsider it might appear that the presence of representatives of so many municipal and state departments would tend to result in a considerable amount of overlapping. Actually, the various facets of the problem that arise in an emergency of this kind are pretty well assigned to various departments and I think that each of them understands what their interest is. It has been my observation in the past that they always work well together.

The problem in the particular instance we are discussing was not one of lack of understanding of an individual mission, but lack of understanding of the degree of hazard involved. Because this was true even of some officials present, the confusion was compounded and the spread of inaccurate information was furthered.

Wide World Photo

Shattered windows and other damage following explosions of finely divided thorium, believed caused by impurities, in a research laboratory doing work under license for the Atomic Energy Commission.

What differences are there between the responsibilities of a contractor and those of a licensee? What is the AEC's role in the case of a licensee?

The Atomic Energy Act of 1954 assigns the responsibility for safe operation of the atomic energy industry to AEC. Both contractors of the AEC and licensees are required to adhere to the health and safety standards of the Commission. In the case of a licensee, AEC must be satisfied, at the time of application for a license, that the work to be undertaken is without hazard to the employee or the public. After the license is granted, the licensee is subject to periodic inspection by the Commission to assure that he is complying with AEC's health and safety standards.

What was the reaction in the community after the incident? Was it about what might have been expected?

The reaction in the community was one of fear and of misunderstanding, and although one might have anticipated some of this, I believe it was greater than we had expected. Both the contractor and the New York Operations Office of AEC were deluged with calls from residents asking whether or not they should evacuate the neighborhood. We understand that some residents were advised by local policemen to keep their children off the streets.

Newspaper and television accounts placed the injured or "exposed" at all the way from 300 to the accurate figure which was 9. These media emphasized the "secret" nature of the work, the "radiation" hazards, and even mentioned the possibility of "sabotage." Both the contractor and AEC subsequently received letters of protest from resident and property-owning groups. These were, of course, answered fully, and this seems to have gone a long way toward reassuring the neighborhood that the plant does not represent a potential radiation hazard. The plant did not at the time of the accident — nor will it in the future — represent a potential radiation hazard.

How can lessons learned at Bayside be applied to other kinds of nuclear accident situations?

I suppose this question is directed primarily at the problems that arose because of the community reaction to the accident. It's important that we realize that the public is unable to think quantitatively about nuclear hazards. As far as the public is concerned, radioactivity is dangerous, regardless of the amount involved. People seem to have little awareness of the fact that radioactivity was known prior to World War II, and has in fact always existed. Despite the educational efforts expended by the Commission and other agencies to date, the thought processes

still seem to run: atomic energy → bomb → radiation → destruction.

I think it would be wise to indoctrinate the residents of a plant neighborhood in the general nature of the work being performed in the plant, and also to give them a realistic evaluation of the potential hazards and a description of the safeguards used to prevent those hazards from materializing.

I cannot emphasize too strongly the need to see to it that fire and police department officials are acquainted with, and understand the nature of, the problems that may arise in a plant in the event of an accident. This need is not peculiar to the nuclear industry. It is customary throughout industry to familiarize the fire department in particular with the hazards that might arise in an industrial fire, especially insofar as chemicals are concerned.

Can you estimate the effect of scare headlines and melodramatic radio and TV accounts used in reporting the Bayside incident?

They contributed to the general hysteria, and the confusion was certainly compounded and prolonged by the misleading statements issued by the news media.

It is interesting to note that although New York City has one of the best and largest science press corps, not one science writer was assigned to cover this story. General-assignment reporters were sent by the city desks; they had no background in atomic energy nor any particular leaning toward science. The number of requests for physical examinations received by the AEC's New York Operations Office from reporters who had visited the scene of the accident has led us to believe that the headlines reflected to some degree the honest fears of the men assigned to cover the story. Although all possible candor was used in responding to inquiries and statements were issued to the media as quickly as the facts were established, uninformed reporting continued throughout the day.

What can be done to indoctrinate the press?

With a large press corps such as we have in New York City, I do not suppose that it is possible to indoctrinate the press as a group separate from the general public. I think that the problem that arose here is one that you face in any emergency. The press wants information within minutes after the accident occurs, whereas it may take an hour or so to develop a factual account of what happened. It is during this interval that effective contact with the press is most essential. Speculation must be carefully screened from facts.

An information headquarters at the scene is important: in any emergency beyond that of a routine neighborhood fire, there should be an emergency information headquarters where people qualified to speak on the matter involved would be accessible to news media representatives. To be effective, such a headquarters should be established by the fire and police departments.*

What specific things can be done to educate the public to accept atomic energy?

There is a need for intensive indoctrination courses at every level of city and state government as well as with the public at large. Most cities, like New York, have access to talented people. For example, the Department of Hospitals here has a group of very competent physicists who are well versed in the problems that may arise out of developments in nuclear energy. I think that every city should make an effort to tap their home resources to design educational programs for those of their personnel who may be involved in handling incidents of this nature.

The AEC has always been pleased to cooperate with any agency that wishes to conduct educational programs. For some years we have, for instance, been cooperating with the New York City Board of Education in conducting training classes for science teachers. We have helped to give teachers information and techniques they can incorporate into their classroom and laboratory work so as to indoctrinate their students in the basic facts of atomic energy and in nuclear physics and chemistry. This type of

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* Editor's Note: Reference to the NFPA QUARTERLY for October 1956, pages 84–90, gives additional thoughts on handling publicity during plant emergencies.

program has been conducted by AEC all over the country, and I think that there should be more and more use of such programs.

Every community should take advantage of the assistance available to it by virtue of the large number of AEC contractors, private industrial projects and universities that have personnel competent in the field of nuclear energy.

What do you think are some of the positive steps that might be taken to improve public understanding of the radiation problem?

I believe that all organizations and agencies — the AEC, the states, private industry, the universities, and any other groups having knowledge in the nuclear field — should assume a portion of the burden of indoctrinating the public in the true facts of radiation, to enable it to distinguish between the inconsequential and the hazardous. Industry and AEC should take the initiative in discussing with the public the possible hazards attendant on any particular nuclear enterprise.

All great technological developments introduce new risks, and atomic energy will be no exception. If progress is to be made, it will have to be made with the understanding of the public and the acceptance by it of the fact that a perfect accident record is not possible. Accidents will occur with increasing frequency as the atomic energy program expands and a larger number of installations become involved in nuclear work. With the cooperation of government and industry, these accidents will be minimized, but they cannot be eliminated entirely.

If the residents in a plant area are cognizant of the true nature of the potential hazard before an accident occurs, they will be much more apt to react from reason and knowledge rather than from emotion. In any community where there is a likelihood of an atomic-energy-connected accident, there must perforce be a few people supervising the work who are knowledgeable in the hazards the work entails. If these persons were to appoint one or two of their number to serve as spokesmen and make themselves known to the local city officials and the press corps as a source of assistance and authoritative information, the public reaction could be expected to be in some degree proportional to the danger involved.

What time element would you place on public indoctrination courses — that is, how urgent is the problem? How fast must solutions be found to keep up with the growth of nuclear industry?

The urgent need for a more informed public is obvious from the community reaction to this incident. On the other hand, the psychology of the public, as it relates to atomic energy, is not going to change overnight and the passage of time may be an essential ingredient of the educational process. Every effort expended helps a little bit. Efforts in the educational field must be expanded, but a well-indoctrinated public is many years off, under the best conditions. Lectures, pamphlets, movies, and other educational tools are all useful and should be brought to bear on this problem, but there is no magic formula for its solution.

Ansul's Fire Fighting School

The largest fire fighting school of its kind in the United States finished its eighth year this October, adding another 500 graduates to its rolls. Altogether, about 2,500 men have been graduated from the school. It is conducted by the Ansul Chemical Company, a leading manufacturer of dry chemical fire extinguishing equipment.

The school was started in response to requests by a number of Ansul customers. They wanted their employees to get the benefit of fire training by specialists in the art at Ansul's fire test station. Now the three-day classes of the school are so popular that the 18 sessions held during the 1957 season were filled to capacity by the preceding March. To make the training as efficient and meaningful as possible, attendance is limited to 25 men per session. However, the number of sessions has been increased each year and total annual attendance has grown from 100 in 1950 to 500 in 1957.

No charge is made for attendance at the school, even though, for example, 35,000 gallons of gasoline, 10,000 gallons of propane, 3,000 gallons of crude oil and 300,000 pounds of dry chemical were used during the 1957 season.

Students Have Varied Backgrounds

The men who come to Ansul's fire school usually already have years of experience. They include fire protection engineers from industry, from insurance companies, from fire depart-

Classroom work is a part of the fire school training given by Ansul Chemical Company. Here, director Frank Hruska lectures on the components of the Ansul hand portable dry chemical extinguishers.

A trainee attacks a gasoline spill fire with a 20 pound Ansul hand portable dry chemical extinguisher.

ments and from the armed forces. The largest percentage of students comes from the petroleum and chemical manufacturing industries. The metal fabrication, natural gas, gas utilities and steel industries are also well represented. A higher percentage every year comes from the aviation manufacturing field. Men have also been sent to the school from the automotive, paper, food, paint, glass and cement industries as well as from the electrical utilities and from all types of transportation companies.

By geographical regions, attendance is heaviest from the midwest. However, men have come to the school from all over the United States as well as from foreign countries. For instance, men have come from the Netherlands West Indies, Venezuela, India, Pakistan, Greece, Iceland, Haiti, Chili, Formosa, Peru and Saudi Arabia. In 1956 thirty-four came from Canada.

School Facilities

Although there is classroom work at the school, most of the training sessions are held on the Ansul training field, where several different types of flammable liquid fires are set up for practice in fire fighting.

At the beginning of a typical three-day session, the trainees fight small gasoline spill fires. These give way to larger spills and then to pan fires of gradually increasing size. Typical industrial fire conditions are simulated for training purposes by igniting a flowing fire in a pail hanging against a metal baffle, a paint dip tank mock-up, and a half drum filled with gasoline on a table.

When high capacity wheeled equipment is brought into play, larger pan and pit fires are ignited. Fuel oil is used first to lessen the hazard until the

Coached by an instructor, a trainee attacks a vertical gasoline jet fire with a hoseline from a dry chemical wheeled extinguisher.

men become accustomed to the extinguishers. Later, gasoline is used as fuel in these fires.

Fires involving propane and gasoline under pressure are also used for training. These are simulated by a liquid propane stream which impinges against a steel baffle, a vertical jet which reproduces a broken pressure gage connection, and an overhead flammable liquid line which is constructed with a leaking flange. The school sessions are climaxed with simulated crash fires which employ large gasoline spills complicated with metal obstacles.

The sessions include training for fighting interior fires in a specially constructed fire-resistive building. Major fires are fought outdoors, of course, but the difference between fighting indoor

and outdoor fires is so great that interior fires are considered mandatory in this training. They are usually much more difficult to fight because of the smoke and hot gases held captive in the enclosure. The experience teaches trainees not to be overconfident, even with a relatively small indoor fire.

Personalized Instruction

Each man attending the Ansul school fights all types of fires. It's a time-consuming proposition, but this is the only way trainees can learn and retain fire fighting techniques. The trainees do not approach the fires alone, however. An instructor goes with each one of them as an extra safety precaution and to coach each student individually on the most effective methods of attack.

Ansul's fire school instructors go through extensive training before they are allowed to conduct actual sessions. They must be expert fire fighters themselves, know how to instruct others in fire fighting, and be willing to meet the Company's safety standards. There has never been a serious fire school accident. Safety is emphasized to protect students while fighting the volatile flammable liquids fires used in the training and to show them how important it is to practice safety in fire fighting.

A group of trainees fill hand portable extinguishers after putting out some of the smaller fires scheduled during the three day course.

A group of safety and fire protection men from one of the nation's leading chemical companies watches as an instructor demonstrates the recharging of a hand portable dry chemical extinguisher.

A key item in the fire school curriculum is instruction on recharging and maintaining hand portable, wheeled and stationary dry chemical extinguishers. Maintenance techniques are taught carefully and in detail with emphasis on the fact that optimum performance of extinguishers depends on the care given them. The trainees recharge and maintain their own equipment, which insures their understanding of the importance of using proper procedures. They also learn inspection techniques which include: making sure the dry chemical tank is full; weighing the gas cartridge; checking fill cap gaskets; operating the activating mechanism; making sure the nozzle and hose are free of obstructions and recording the inspection on a tag.

Frank Hruska, director of the Ansul Chemical Company fire school, awards a diploma to a trainee (right) who has successfully completed the course. Trainees are also given special fire school ties which are exclusive with graduates of the school.

During the classroom discussion and lecture periods, the trainees see the latest films available on fire fighting practices. The films are produced not only by Ansul, but by other organizations such as Factory Mutual Laboratories, Audio Productions, Inc. and the Texas Industrial Film Company. Among the films shown during 1957 were the following:

Know Your Fire Extinguisher
Factory Mutual Engineering Division

Flammable Liquid Fire Safety
Factory Mutual Engineering Division

Operation and Maintenance of Ansul Hand Portable Extinguishers
Ansul Chemical Company

Ansul Wheeled Extinguishers
Ansul Chemical Company

Natural Gas Fires
Ansul Chemical Company

Vinyl Chloride and Propane Fires
Ansul Chemical Company

Crash Fire Fighting
Ansul Chemical Company

From these films and from lectures, the men learn the theory of the action of dry chemical on fire, fundamentals of fire protection and common industrial fire hazards. They also study Ansul's automatic dry chemical piped systems which are demonstrated both with total flooding and local application.

Training Used in Various Ways

Many companies send a few men to the classes each season so that a large segment of their fire fighting brigades will receive the training over a period of years. Other companies enroll enough men to fill the quota for an entire class so they can concentrate on the specific typical hazards found in their own plants. The Ohio Oil Company, du Pont and John Deere have followed the latter pattern during the last few years.

Every spring, seniors in the fire protection and safety engineering program at the Illinois Institute of Technology attend a special class sponsored by Ansul. They use various types of fire extinguishing equipment on flammable liquid and gas fires, metal fires and ordinary combustible fires. This gives them practical training to back up their school instruction.

All but one of Ansul's fire school graduates are men. The exception is Mrs. Mabel Gerold, manager of a bulk plant and a fleet of petroleum tank trucks. She attacked all the fires used regularly in the fire school curriculum and completed the course successfully.

Friction Spark Ignition in Crash Fires

By John A. Campbell

National Advisory Committee for Aeronautics

Lewis Flight Propulsion Laboratory

A study was made to determine if common aircraft metals produce friction sparks capable of igniting combustibles that might be spilled in an airplane crash. Samples of aluminum, titanium, magnesium, chrome-molybdenum steel, and stainless steel were dragged over both concrete and asphalt runways while a combustible mixture of gasoline, JP-4 fuel, kerosene, or preheated oil was sprayed around the sample.

No ignitions occurred from sliding aluminum at bearing pressures up to 1455 pounds per square inch and slide speeds up to 40 miles per hour. From a study of these results and of related literature, it is believed that aluminum would not be an ignition source even at higher bearing pressures and slide speeds. Titanium, magnesium, chrome-molybdenum steel, and stainless steel produced friction sparks that ignited the combustibles at sliding speeds and bearing pressures well below those that could be expected in a crash.

Introduction

Hot or burning metal particles, commonly known as friction sparks, abraded from an aircraft structure during a crash may contact spilled combustibles and start a fire. It is known from experimental crashes (Reference 1) that abraded steel particles can ignite spilled gasoline. In these experimental crashes, steel and aluminum were the only metals studied; and no fires resulted from abraded aluminum particles. Since only steel and aluminum had been studied it was desirable to expand the investigation to cover other aircraft metals and other combustibles. The purpose of the present study, therefore, was to determine which aircraft metals sliding over a runway would ignite spilled combustibles by friction sparks and the slide speeds and bearing pressures under which ignition would occur.

The probability that a friction spark will ignite a combustible fuel-air mixture depends on the character of the fuel and the thermal energy of the spark. The thermal energy in a friction spark depends largely on the energy put into the metal, the hardness of the metal, and the temperature at which particles of the metal burn. The energy put into the metal, and thus the thermal energy of the friction spark, will increase with increased bearing pressure and increased slide speed. The greater the hardness of the metal, the greater the energy required to abrade particles from the metal. If the metal particles reach their ignition temperature in being abraded, they will burn. This oxidation then further increases the thermal energy available for igniting combustible mixtures. Although the presence of luminous metal particles indicates that they are burning (Reference 2), it does not necessarily indicate that combustibles, such as gasoline, will be ignited. The size and temperature of the particles must be such that sufficient thermal energy can be transmitted to the combustible to raise it to its ignition temperature (Reference 3).

The surfaces of the parent metal or metal smeared on to the runway may also be hot enough to ignite combustible fuel-air mixtures. This possibility was studied only when the friction sparks did not act as an ignition source.

Based on Technical Note 4024 issued by the National Advisory Committee for Aeronautics, Washington, D. C., dated May 1957.

Hoist used to raise or lower framework and sample
Framework hinged to truck carries sample of aircraft metal, fuel spray system, and weights for placing a bearing load on the sample

Figure 1. Experimental apparatus.

This study of friction-spark ignition was conducted by dragging a sample of typical aircraft metal over both concrete and asphalt runways at various speeds and bearing pressures while the sample was surrounded with a combustible fuel-air mixture. (The term concrete runway indicates a runway constructed of portland-cement concrete, while asphalt runway indicates a runway surfaced with asphaltic concrete. A slag or limestone aggregate was used for both types of concrete.)

The type of metal, the bearing pressure on the metal, the slide speed, and the fuel were varied to simulate, within the limitations of the experimental apparatus, the conditions that might be encountered in an airplane crash on a paved runway. Five types of metal were studied: 2024-T3 aluminum alloy, Ti-100A titanium alloy, FS1 magnesium alloy, chrome-molybdenum (SAE 4130) steel, and AISI 347 stainless steel. 100/130-Octane aviation gasoline, JP-4 fuel, kerosene, and preheated SAE No. 5

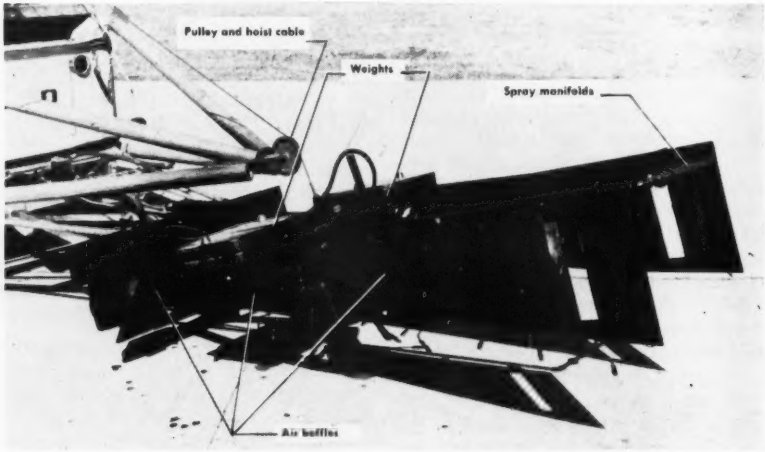

Figure 2. Frame of test apparatus holding weights, fuel spray system and air baffles.

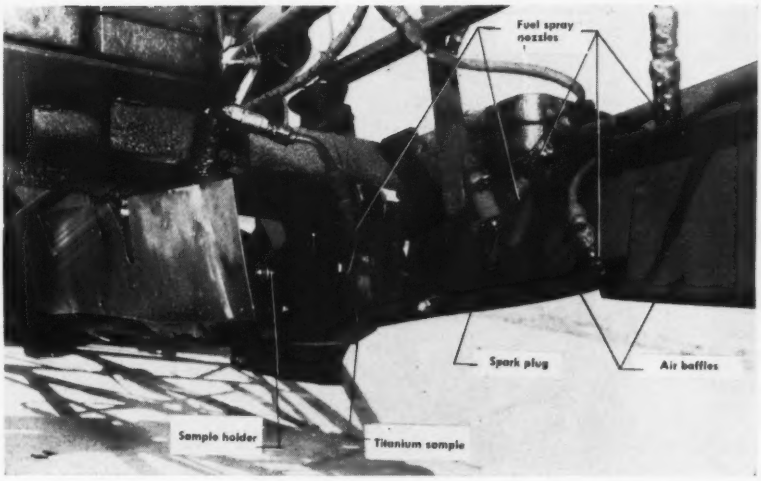

Figure 3. Metal sample held in holder and surrounded by fuel spray nozzles.

lubricating oil were sprayed around the sample to provide the combustible atmosphere.

Apparatus and Procedure

The drag apparatus (Figure 1) was constructed so that a bearing load could be applied to a metal sample and the sample could be pulled over a runway surface while surrounded by a combustible fuel-air mixture. A steel framework was attached by hinge pins to a pickup truck; and the metal sample, the weights, and the fuel spray system were attached to this framework. The details of the apparatus are illustrated in Figures 2 and 3.

The metal sample was lowered to, or raised from, the runway by a hoist on the truck and a cable attached to the framework. A platform on the framework held weights which, combined with the weight of the framework, placed a bearing load on the metal sample. The bearing pressure on the sample could be varied from a minimum of about 20 pounds per square inch to a maximum of 1455 pounds per square inch by changing the number of weights and the surface area of the metal sample. The sliding surfaces of the samples were varied from ¾-inch-diameter to a 10-by 1-inch rectangle to obtain a large range of bearing pressures.

During a crash, fuel spilled from ruptured tanks into the airstream produces large clouds of fuel mist around the aircraft. Damaged sections of the lubrication system can also produce a cloud of oil vapor and mist around the nacelles (Reference 1). A combustible atmosphere similar to that which could be encountered in a crash was produced by a fuel spray system (Figure 4). The spray nozzles were located so as to surround the metal sample and the abraded particles with the combustible mist-air mixture. The fuel flow was adjusted to compensate for wind and slide speeds to provide a combustible atmosphere.

Baffles attached to the front and sides of the spray manifold protected against excessive fuel dilution by the air at slide speeds up to 40 miles per hour and in moderate wind. A spark plug suspended behind the sample was used to check the presence of a combustible fuel-air mixture. The spark plug was located

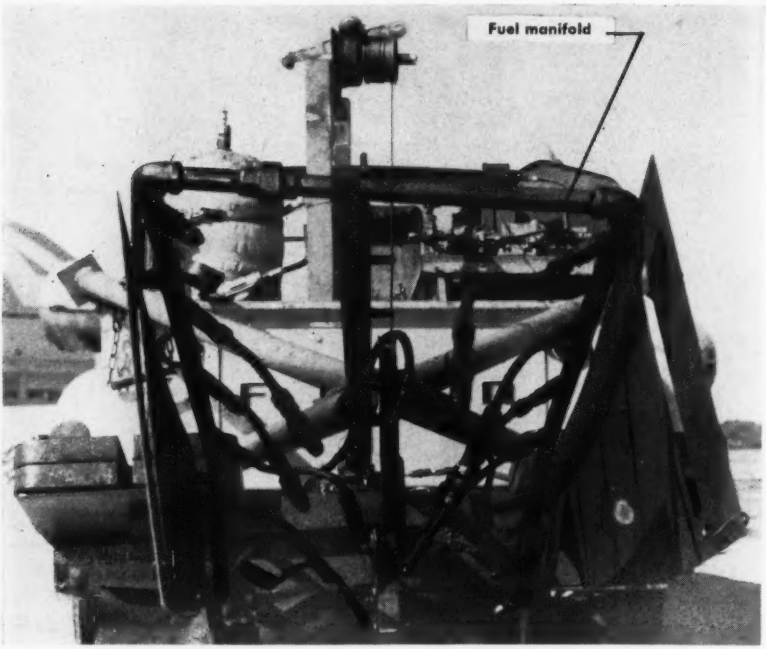

Figure 4. Fuel spray system on test apparatus.

directly adjacent to or anywhere up to 4 feet behind the sliding sample.

Before starting the friction-ignition experiments, the fuel flow necessary to obtain a combustible mixture at various speeds under the prevailing wind conditions was determined. The entire area up to 4 feet behind the sample was explored with a spark plug to be sure that there was a combustible mixture throughout. The presence of a combustible mixture in the fuel spray zone was checked before each day's experiments and after any change in wind velocity during the day.

After the fuel flow for obtaining a combustible mixture had been determined, each run was made as follows: The truck was accelerated to the desired speed as indicated by the truck speedometer. The spray system was turned on during the acceleration, and at the desired speed the metal sample was lowered to the runway. If ignition did not occur, the spark plug was energized near the end of the run and before the speed was reduced to be certain that a combustible mixture was present. The slide time until ignition occurred was measured with a stop watch.

This procedure was repeated with each metal for different slide speeds, bearing pressures, combustibles, and types of runway. Initial experiments were generally made at a moderate bearing pressure and a slide speed of 20 miles per hour. Additional experiments were then made at different bearing pressures and slide speeds to determine within the limitations of the apparatus the lowest bearing pressures and slide speeds at which ignition would occur.

Results and Discussion

The results of the experiments are presented individually for each metal stud-

ied. The conditions of the experiments with each metal on concrete and asphalt runways and with the different fuel sprays are summarized in Table I.

Aluminum

2024-T3 Aluminum alloy sliding over either concrete or asphalt runways at speeds up to 40 miles per hour and bearing pressures up to 1455 pounds per square inch did not produce friction sparks that would ignite the combustible mixture. The complete range of speeds and bearing pressures was applied to the sample on a concrete runway with gasoline, JP-4 fuel, kerosene, or preheated SAE No. 5 oil providing the combustible fuel-air mixture. None of these combustibles was ignited. Aluminum samples were

Table 1

Summary of Experimental Conditions

Metal	Runway	Fuel spray	Number of trials	Number of ignitions	Bearing pressures, psi	Slide speeds, mph	Maximum slide distance, ft
2024-T3 Aluminum alloy	Concrete	Gasoline	30	None	52 to 1455	10 to 40	2600
	Concrete	JP-4 Fuel	14	None	63 to 1455	10 to 40	2200
	Concrete	Kerosene	12	None	64 and 1455	20 to 40	1850
	Concrete	SAE No. 5 lubricating oil	15	None	64 to 1455	20 to 40	2060
	Asphalt	JP-4 Fuel	18	None	64 to 1455	20 to 40	1350
Ti-100A Titanium alloy	Concrete	Gasoline	20	20	21 to 143	<5 to 40	105
	Concrete	JP-4 Fuel	6	6	21 to 24	<5 to 20	320
	Concrete	Kerosene	6	6	23 to 26	<5 to 20	330
	Concrete	SAE No. 5 lubricating oil	7	7	21	5 to 20	15
	Asphalt	JP-4 Fuel	8	8	21 to 34	<5 to 20	160
FS1 Magnesium alloy	Concrete	Gasoline	15	15	37 to 81	10 to 40	1700
	Concrete	Gasoline	12	4	20 to 30	10 to 40	2750
	Concrete	JP-4 Fuel	4	4	37 to 57	10 and 20	540
	Concrete	JP-4 Fuel	5	3	18 to 25	10 and 20	1500
Chrome-molybdenum (SAE 4130) steel	Concrete	Gasoline	12	12	20 to 1280	10 to 40	1000
	Concrete	Gasoline	2	0	17	10	1100
	Concrete	JP-4 Fuel	19	19	19 to 816	10 to 40	1050
	Concrete	Kerosene	38	[a]22	23 to 414	20 to 35	2060
	Concrete	SAE No. 5 lubricating oil	7	7	32 to 64	20 and 30	1450
	Asphalt	JP-4 Fuel	62	[a]20	44 to 816	10 to 40	1850
AISI 347 Stainless steel	Concrete	Gasoline	3	2	66 to 77	20	1790
	Concrete	Gasoline	4	4	50	30	1100
	Concrete	Gasoline	5	1	50	20	1820
	Concrete	Gasoline	13	2	23 to 34	20 and 30	2060
	Concrete	JP-4 Fuel	3	3	66	20 and 30	1320
	Concrete	JP-4 Fuel	3	3	50	30	920
	Concrete	JP-4 Fuel	3	1	50	20	1440
	Concrete	JP-4 Fuel	5	1	34	20 and 30	1640
	Concrete	Kerosene	7	5	50	20 and 30	1700
	Concrete	Kerosene	6	2	34	20 and 30	1640

[a] Inconsistent ignitions.

also dragged over an asphalt runway at slide speeds of 20 to 40 miles per hour with bearing pressures of 64 to 1455 pounds per square inch applied to the sample without igniting a JP-4 fuel mist.

The abraded aluminum left a smear of metal on the runway surface and sprayed aluminum dust behind the sample.

Small metal particles must be very hot to ignite combustible vapor-air mixtures. A sphere 0.25 inch in diameter must be heated to approximately 1800° F. to ignite a combustible pentane-air mixture. The ignition temperature of pentane is about the same as that for gasoline. Since the melting temperature of 2024-T3 aluminum alloy is 935° to 1180° F. (Reference 4), globules of molten aluminum over ¼ inch in diameter would be required to ignite the combustible vapor-air mixture. Since it is very unlikely globules of molten aluminum as large as ¼ inch diameter would be produced when aluminum is being abraded in this fashion, hot abraded aluminum particles are not considered to be a crash-fire ignition source.

There also was no indication that burning aluminum particles would be an ignition source. Normal grinding operations of aluminum do not produce luminous particles (Reference 2), and no luminous particles were observed in these runway experiments.

In order to determine if the surface of the sliding parent aluminum or the hot metal smeared on the runway would be hot enough to ignite the combustible fuel-air mixture, an additional series of experiments were made. A sample with a bearing load applied was dragged over a concrete runway while fuel was sprayed around the sample and on the runway in front of the sample. At the end of the runway, the sample was abruptly stopped and for about 30 seconds fuel was sprayed intermittently to maintain a combustible atmosphere around the hot sample. No ignitions occurred with fuel sprays of gasoline, JP-4 fuel, or preheated SAE No. 5 oil.

On the basis of these experiments and the literature study, it is believed aluminum would not be a crash-fire ignition source

Table II

Minimum Conditions at Which Ignition Occurred with Ti-100A Titanium Alloy

Runway	Fuel spray	Lowest slide speed and shortest slide time at which ignition occurred with minimum bearing pressure used.			Lowest bearing pressure and shortest slide time at which ignition occurred with minimum slide speed used.			Lowest bearing pressure and slowest slide speed at which ignition occurred at shortest slide time.		
		Speed, mph	Time, sec	Press., psi	Press., psi	Time, sec	Speed, mph	Press., psi	Speed, mph	Time, sec
Concrete	100/130-Octane gasoline	10	Instantaneous	21	38	6	<5	21	10	Instantaneous
								38	5	Instantaneous
	JP-4 Fuel	<5	71	21	21	71	<5	21	5	Instantaneous
		5	Instantaneous	21						
	Kerosene	<5	6	23	23	6	<5	26	5	Instantaneous
	Preheated SAE No. 5 oil	5	Instantaneous	21	21	Instantaneous	5	21	5	Instantaneous
Asphalt	JP-4 Fuel	10	Instantaneous	21	24	35	<5	21	10	Instantaneous
								26	5	Instantaneous

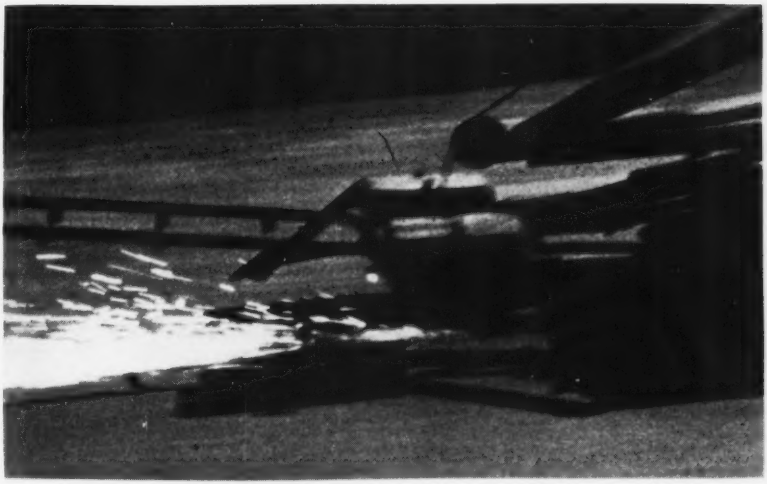

Figure 5. Titanium sparks from friction on runway at 10 mph.

even though the sliding speed and bearing pressure were greater in a crash than those used in this study.

Titanium

T1-100A Titanium alloy sliding over both concrete and asphalt runways produced sparks that ignited the combustible mist in all experiments. The conditions at which ignition occurred with minimum bearing pressures, with minimum slide speed, or with minimum slide time are summarized for titanium in Table II. In these experiments the minimum bearing pressures applied to the sample were from 21 to 23 pounds per square inch and the minimum slide speeds were less than 5 miles per hour. At slide speeds of 10 miles per hour and above, the fuel mist was ignited as soon as the sample was lowered to the runway. At slower speeds the sample had to be dragged up to 330 feet before ignition occurred. In all the experiments the fuel mist was ignited as soon as sparks were observed.

Very large quantities of large bright sparks (Figure 5) could be seen when the metal slid on the runway at speeds of 10 miles per hour and above without fuel being sprayed. At slide speeds below 10 miles per hour only occasional sparks were produced. The bright sparks seen in this study indicate that the abraded particles are burning and have considerable thermal energy.

The ease with which titanium sparks are produced and the fact that they ignited gasoline, kerosene, JP-4 fuel, and preh ·ed SAE No. 5 lubricating oil indicate that they are a very probable ignition source of a crash fire if combustible fuel-air mixtures occur in the crash in the spark zone.

Magnesium

Friction sparks produced by FS1 magnesium alloy sliding over a concrete runway ignited both gasoline and JP-4 fuel mists. Gasoline and JP-4 fuel were the only combustibles used in this study. The minimum conditions at which ignition occurred are summarized in Table III. At bearing pressures of 37 pounds per square inch and above, ignition occurred in all the experiments. At bearing pressures of 18 to 30 pounds per square inch, ignition occurred in four of twelve trials using gasoline and in three of five trials using JP-4 fuel. In only one experiment, at a bearing pressure of 54 pounds per square inch and a slide speed of 30 miles per hour, was the fuel mist ignited as soon as the sample was lowered to the runway surface. In all the other experiments, it was

Table III

Minimum Conditions at Which Ignition Occurred with FS1 Magnesium Alloy

Runway	Fuel spray	Lowest slide speed and shortest slide time at which ignition occurred with minimum bearing pressure used.			Lowest bearing pressure and shortest slide time at which ignition occurred with minimum slide speed used.			Lowest bearing pressure and slowest slide speed at which ignition occurred at shortest slide time.		
		Speed, mph	Time, sec	Press., psi	Press., psi	Time, sec	Speed, mph	Press., psi	Speed, mph	Time, sec
Concrete	100/130-Octane gasoline	20	5	19	37	5	10	54	30	Instantaneous
	JP-4 Fuel	20	51	18	37	7	10	37	10	7

necessary to drag the magnesium over the runway for a short distance before ignition occurred.

The sliding magnesium left traces of the metal on the runway and deposited a residue of magnesium powder on the rear of the fuel spray manifold. Large bright flashes of burning magnesium powder (Figure 6) were produced behind the sample when it was dragged without fuel being sprayed. These flashes occurred intermittently, and their frequency and size increased as the slide distance increased.

No individual glowing particles were observed in these experiments. Normal magnesium grinding operations do not produce luminous particles (Reference 2). Although the velocities involved in grinding are greater than the slide speed in these runway experiments, the bearing pressures and rate of metal abrasion were greater in the runway experiments than in the grinding operations. The greater bearing pressure and accompanying increased abrasion are apparently responsible for the added energy that ignites the abraded magnesium powder.

Since magnesium is a relatively soft metal, little mechanical energy is required to tear the particles from the parent metal. However, since the metal particles ignite at a

Figure 6. Burning magnesium powder from friction heat.

relatively low temperature, 970° to 1005° F. (Reference 5), not much energy is required for ignition and the powdered metal ignites easily. Once ignited, the burning powder becomes a powerful ignition source. The theoretical flame temperature of pure magnesium is 8760° F. (Reference 6). The actual flame temperature of this alloy will be lower but still quite hot. The ease with which magnesium particles burn, the high flame temperatures, and the size of the burning magnesium flashes indicate that magnesium aircraft parts will produce friction sparks on sliding contact with the runway that can easily start a crash fire.

Chrome-Molybdenum Steel

Friction sparks produced by chrome-molybdenum (SAE 4130) steel sliding over both concrete and asphalt runways ignited all the combustibles studied. The minimum conditions at which ignition occurred are shown in Table IV.

Gasoline, JP-4 fuel, kerosene, and preheated SAE No. 5 oil mists were ignited by steel sliding over a concrete runway at bearing pressures as low as 19 to 32 pounds per square inch and slide speeds as low as 10 and 20 miles per hour. However, ignitions of the kerosene mist occurred in only 22 of the 38 trials throughout the range of bearing pressures and slide speeds used.

In no experiments did ignition occur as soon as the sample was lowered to the runway. A few ignitions occurred after 2 to 3 seconds of sliding on a concrete runway, but in the majority of the experiments the sample slid for a much longer time interval. Immediately after initial contact of the steel sample with the runway, only a few small sparks were observed. The number and intensity of the sparks increased as the sample slid and appeared to reach a maximum after a short distance.

On an asphalt runway, sparks from the steel occasionally ignited the JP-4 fuel spray at bearing pressures of 108 to 816 pounds per square inch and slide speeds of 10 to 40 miles per hour. In some of these experiments, the ignitions occurred 10 to 15 feet behind the sample and did not propagate throughout the fuel mist.

Table IV

Minimum Conditions at Which Ignition Occurred with Chrome-Molybdenum (SAE 4130) Steel

Runway	Fuel spray	Lowest slide speed and shortest slide time at which ignition occurred with minimum bearing pressure used.			Lowest bearing pressure and shortest slide time at which ignition occurred with minimum slide speed used.			Lowest bearing pressure and slowest slide speed at which ignition occurred at shortest slide time.		
		Speed, mph	Time, sec	Press., psi	Press., psi	Time, sec	Speed, mph	Press., psi	Speed, mph	Time, sec
Concrete	100/130-Octane gasoline	20	12	[a]20	145	15	10	145	20	8
	JP-4 Fuel	10	73	19	19 145	73 23	10 10	24	20	2
	Kerosene [b]	20	29	23	23 280	29 4	20 20	280	30	2
	Preheated SAE No. 5 oil	20	11	32	32 64	11 7	20 20	64	20	7
Asphalt	JP-4 Fuel [b]	20	20	[a]108	680 [c]816	15 10	10 10	548 [c]816	30 10	10 10

[a] Not lowest used but lowest that resulted in ignition. [b] Inconsistent ignitions. [c] Ignition 10 to 15 ft. behind sample.

On an asphalt runway, the minimum slide time before ignition occurred was 10 seconds. The slide distance, before a maximum quantity of sparks was produced, was longer on an asphalt runway than on a concrete one.

The size and temperature of the particles abraded on the asphalt runway are apparently of marginal thermal energy for igniting the fuel mist. The ignitions which occurred 10 to 15 feet behind the sample may be the result of a longer residence time of the abraded particle with the fuel. In these experiments, an assured combustible atmosphere is present only 4 feet behind the sample and will not occur consistently 10 to 15 feet behind the sample. The infrequent ignitions 10 to 15 feet behind the sample may be due to the inconsistent presence of a combustible mixture and the marginal size and temperature of the abraded particles. In an actual crash, there may be a larger zone of a combustible atmosphere which might increase the probability of ignition when steel is sliding over an asphalt runway.

Stainless Steel

Friction sparks produced by AISI 347 stainless steel sliding over a concrete runway ignited mists of gasoline, JP-4 fuel, and kerosene. The minimum conditions at which ignition occurred are summarized in Table V. At bearing pressures below 50 pounds per square inch, ignitions occurred in only about one-fifth of the experiments. At higher bearing pressures, ignitions occurred in about one-half of the experiments at slide speeds of 20 miles per hour but in all the experiments at 30 miles per hour.

Fewer sparks appeared to be produced by the sliding of stainless steel than by the sliding of chrome-molybdenum (SAE 4130) steel. In most of the experiments, the sample had to slide a relatively long distance before ignition occurred.

These experiments indicate that the friction sparks from stainless steel are also a potential ignition source of an aircraft crash fire.

Concluding Remarks

As a result of this study, it is apparent that aluminum is the safest metal with respect to friction sparks since it produced no visible sparks and did not ignite combustible mists even at the maximum obtainable bearing pressure (1455 psi) and slide speed (40 mph). Although aluminum will not produce hazardous friction sparks, the thin aluminum skin on an aircraft may be torn in a crash or be abraded by sliding and thereby expose more hazardous metals. In an ordinary belly landing, however, an aluminum fuselage skin would be worn through only in localized spots when sliding on a runway

Table V

Minimum Conditions at Which Ignition Occurred with AISI 347 Stainless Steel

Runway	Fuel spray	Lowest slide speed and shortest slide time at which ignition occurred with minimum bearing pressure used.			Lowest bearing pressure and shortest slide time at which ignition occurred with minimum slide speed used.			Lowest bearing pressure and slowest slide speed at which ignition occurred at shortest slide time.		
		Speed, mph	Time, sec	Press., psi	Press., psi	Time, sec	Speed, mph	Press., psi	Speed, mph	Time, sec
Concrete	100/130-Octane gasoline	20	54	[a]27	27 77	54 7	20 20	77	20	7
	JP-4 Fuel	30	26	34	50	42	20	50	30	3
	Kerosene	20	15	34	34 50	15 5	20 20	50	20	5

a Not lowest used but lowest that resulted in ignition.

because the weight of the aircraft is distributed over a relatively large area and the unit bearing pressure is low. Thus, the possibility of exposing more hazardous metals is small under these circumstances.

Of all the metals studied, titanium ignited the fuel mists most readily; but magnesium, chrome-molybdenum steel, and stainless steel all ignited the fuel mists at slide speeds and bearing pressures less than those to be expected in an airplane crash. Therefore, any of these metals sliding over a runway can be a crash-fire ignition source.

Although titanium produced hazardous friction sparks on an asphalt runway as readily as on a concrete runway, chrome-molybdenum steel did not. However, the chrome-molybdenum steel sliding on an asphalt runway ignited the fuel spray at moderate speeds and bearing pressures. It is believed that magnesium and stainless steel sliding on an asphalt runway would produce sparks under approximately the same conditions as did chrome-molybdenum steel. The probability of a metal producing hazardous sparks on an asphalt runway having an aggregate of hard rocks, such as quartz or flint, would be greater than on the asphalt runways used, which had an aggregate of slag or limestone. Although an asphalt runway is slightly safer with respect to friction sparks from some metals, some fuel when spilled may dissolve the asphalt; and, if an ignition did occur, the asphalt would add fuel to the fire.

Titanium briefly striking another hard surface, such as a stone or other piece of metal, will probably produce hazardous friction sparks; but magnesium, chrome-molybdenum steel, and stainless steel are less likely to. In these studies titanium instantly ignited the fuel mists at low slide speeds and bearing pressures. However, magnesium, chrome-molybdenum steel, and stainless steel usually had to be preheated by being dragged over the runway for a short distance before they produced sparks that would ignite the fuel mists. Since the metal would not be preheated in a brief contact, magnesium, chrome-molybdenum steel, and stainless steel are less likely to produce hazardous sparks by striking isolated stones or other hard surfaces if an emergency landing is made on an earthen surface.

Fuels of low volatility may be slightly safer with respect to friction-spark ignitions than fuels of high volatility. The fuel mists must be vaporized and then raised to their ignition temperatures before they burn. Gasoline-type fuels, being highly volatile, will readily vaporize at ambient temperatures, while the heat for vaporizing low-volatile kerosene-type fuels must come partly from the ignition source. However, the ignition temperature of kerosene-type fuels is lower than that of gasoline. These two effects thus tend to cancel each other, and the net effect of decreasing the volatility is not as great as expected. The extent of this benefit with respect to friction sparks is indicated by comparing the ease with which sparks from chrome-molybdenum steel ignited gasoline and kerosene.

Although the kerosene mist was ignited at nearly as low bearing pressures and slide speeds as was the gasoline mist, the ignitions of kerosene occurred inconsistently throughout the range of the experiments. The thermal energy of the friction sparks from chrome-molybdenum steel is apparently of marginal thermal energy to both vaporize and ignite the kerosene mist. However, sparks of large thermal energy, such as from titanium, will ignite mists of low-volatile fuels as easily as high-volatile fuels.

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Nuclear Bomb Fire Defense

By Theodore J. Wang

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EDITOR'S NOTE: This article is a portion of a large classified report on the defense of the United States prepared by the Operations Research Office of The Johns Hopkins University under contract with the Department of the Army. Authority has been secured by the author for its publication herein.

In areas which are sufficiently removed from ground zero to be outside the region of total blast destruction the menace of fire is of major concern. In the particular case of an inaccurate burst wherein the ground zero is removed many miles from the heart of a city, the only serious destruction to the city may be that attributed to fire. In any case, it is in the areas of moderate to negligible blast damage that fire protection can effect the saving of many lives and structures.

Fires associated with nuclear bursts are classified as "primary" fires if they originate directly through the heat of the explosion, that is, from the thermal radiation of the fireball; and they are classified as "secondary" fires if they originate indirectly through blast, that is, through missile effects and ruptures, which serve to expose combustible materials to firebrands and flames. Both primary and secondary fires can be appreciably limited in extent and in number by the simple expedient of good housekeeping through the elimination or safe enclosure of materials that are easily ignited.

Collections of readily ignitable materials which constitute possible nuclei of incipient fires are described as "ignition points." On-the-site inspections around the country by the U. S. Forest Service have revealed the existence of thousands of needless ignition points per square mile in many potential target communities.* In most instances the offensive items are piles of newspaper; other ignition points involve rags, dead leaves and grass, rotted and splintered wood, wood shingles, awnings, and deteriorated house trim. A variety of ignition points are also found to exist indoors in the form of curtains, window shades, cotton cloth, and paper items.

Graphical demonstration of the role of ignition points in establishing fires is provided by the Federal Civil Defense Administration's motion picture film, *The House in the Middle*. This film, which was taken at a Nevada weapons effects test, deals with exposure of houses at such distance from a nuclear detonation that blast effects were minor. In each instance where ignition points abounded, the houses involved were burned to the ground; whereas in comparable situations where ignition points had been largely eliminated, the houses involved were left intact and structurally sound, only mildly charred, following the burst.

Ignition points individually may be regarded as small cause for concern, but collectively, under simultaneous triggering by a nuclear explosion, they represent the initiation of a mass fire

Special acknowledgment is tendered by the author to Horatio Bond, Chief Engineer of the National Fire Protection Association, for his helpful assistance in the preparation of this material on fire. Reference is also directed to a presentation of similar content by Willard Bascom: *Civil Defense Against Great Fires*, National Academy of Sciences, 1956.

*A similar check of ignition points within several military establishments has been undertaken by the Naval Radiological Defense Laboratory: TR-101, *Thermal Vulnerability of Military Establishments*, NRDL, 1955.

which could assume serious proportions. Wind can enhance fire action by spreading sparks and firebrands and by providing oxygen needed for combustion.

Conflagrations vs. Fire Storms

A mass fire which is fanned by natural winds is termed a "conflagration." Examples of conflagration are the Chicago fire of 1871 and the San Francisco fire of 1906. A mass fire which creates its own winds through convection processes is known as a "fire storm." In the fire storm the heated air over the core of the fire rises, and is displaced by a rush of cooler air inward from the peripheral areas. In a typical fire storm this in-draft attains hurricane velocities, and all of the combustible material within an expanse of a square mile or more is consumed by the blaze within a matter of hours. Examples of the fire storm are the fire associated with the nuclear bombing at Hiroshima in 1945 and the fire set by one incendiary raid on Hamburg in 1943. The conflagration type of fire admits of conceivable escape — street rubble and fallout permitting — by those individuals who are able to flee to the sides or to the rear of the advancing flames. The fire storm, on the other hand, presents a virtual trap for those who are caught within its confines.

Studies on the limited number of fire storms which have occurred to date suggest that the basic requirements to sustain a fire storm are: (1) a region of combustible material covering at least one square mile of ground area, and (2) a density of structures within this region in excess of twenty percent roof-to-ground ratio. Examination of large American cities reveals that almost every important U. S. potential target city has conflagration possibilities to varying degrees, a few of the very largest have the conditions described to make a fire storm possible.

Importance of Trained Civilians

Since following a nuclear explosion numerous small individual ignitions may collectively contribute toward creating ultimately a large and devastating fire, it is apparent that immediate first aid at each local fire position is imperative if the larger fire is to be prevented or minimized. This means that fire fighting would have to be initiated immediately after the nuclear burst (or as soon thereafter as the prompt radiation permits) by individual survivors and by groups of survivors using hand tools at every local position within the hazard area. The regular fire service cannot be expected to fight these local incipient fires because there are apt to be far too many of the separate fires, and because most of these fires may be inaccessible to large scale fire equipment anyhow on account of the impediment of blast rubble in the streets.

British Fire Guards

The British experience in World War II may be of some value in local fire fighting. In Britain "fire guard" organizations of trained civilians were set up with the specific objective of extinguishing small local fires. The fire guards worked with stirrup pumps and buckets of water; they were paid in accordance with their hours of service; and they operated independently of the regular public fire service, the latter being reserved for attending designated important properties that were within their reach.

A severe handicap to fire guards and to the regular service alike in a nuclear war is heavy fallout, a condition which might prevail for days or for weeks following an explosion and which might limit the defense against fire to automatic devices like sprinkler systems. This consideration does not preclude intensively hand-fighting incipient fires for the first half hour or more — until fallout appears — following an initial explosion; but it does point up one incentive to the enemy (and, hence, it suggests the likelihood of occurrence) of *successive* explosions on any target wherein the intention of the enemy is to exploit fire destruction during fallout.

Need To Consolidate Fire Services

There is some question as to the value of increasing the size of existing regular fire systems in anticipation of a nuclear war. However, there appears to be merit in combining the several municipal and township fire units within any one state into a single co-ordinated fire system. Wherever such a merger is contemplated, it should be executed well in advance of its anticipated wartime need so that the inevitable miscellaneous problems of organization could be resolved at leisure and would not be superimposed upon the major problem of combating enemy destruction. There appears to be agreement that consolidation would improve fire department service and reduce peacetime costs.

It is to be expected that municipal water service will be disrupted by broken mains in a nuclear blast. Some provision for this contingency is suggested by British and German wartime experience with static water reservoirs, that is, both conventional roof tanks with gravity outlets, and street-level tanks with auxiliary gas engine driven pumps. A comprehensive engineering design for ground-level reservoirs for the downtown areas of Boston and of Cambridge, Massachusetts, was reported in the NFPA QUARTERLY for April 1954. The over-all system involves 175 reservoirs and two natural ponds; the total capacity of the system is 5,000,000 gallons. The estimated cost is $1,410,000 exclusive of legal expenses and of land costs, and exclusive of accessory materials which had been furnished to the state of Massachusetts by the Federal Civil Defense Administration. These accessories provided by FCDA consist of 20 miles of 8-inch quick coupling pipe (for joining the reservoirs into their own independent water system) and twenty 1500-gallon-per-minute pump assemblies. Some precaution, such as circulation, would be necessary with reservoir systems to avoid freezing during cold weather.

Fire Breaks — City Planning

Judicious city planning can economically provide substantial fire protection through fire breaks by the forbidding of new construction either on the sites of razed slum areas or on any existing lots in already congested areas.

Window Protection Problems

It has been suggested that individuals can reduce the hazard of ignition of internal fuels by drawing shades, closing windows, and whitewashing windows following warning of imminent attack. The objective of these techniques is to hold down radiant thermal energy entering a building. However, these same techniques in some cases introduce opportunity for adverse effects. Closed windows prevent that alleviation of blast effect which open windows might allow through reduction of the pressure differential inside and out. Further, closed windows increase the chance for destruction by flying glass fragments and, correspondingly, they increase the chance for initiation of secondary fires. (Open windows, doors, and tent flaps are conventional protective practice of the AEC at nuclear bomb tests.) It may be that white adhesive taping of closed windows as mentioned by Bascom in his report (see footnote, page 134) provides an optimum solution of the window problem. Drawn window shades receive the full exposure of the incident radiation and may, themselves, constitute a fire hazard. In any event, the window problem appears to merit additional study in view of the relative ease of effecting whatever is considered to be the most desirable action.

Hazards in Bomb Shelters

The interiors of personnel shelters present a special fire protection problem inasmuch as these shelters would be essentially sealed off from the outside during their period of occupancy. Individuals trapped within a burning shelter could face the gruesome choice

of exposure (a) to the insidious effects of fallout if they fled to the outside, or (b) to the immediate effects of burning and suffocation if they remained on the inside. This situation, incidentally, provides the necessary ingredients for panic. Accordingly, shelters and their contents should be designed with a careful view toward fire resistant features; further, considerable discretion should be employed by the occupants of any shelter in the use of flames or heat therein.

If a shelter is located underground in a densely settled urban area where there is danger of large fires overhead, then the internal shelter air should be recirculated for the first several hours following a nuclear burst in order to avoid drawing in outside air, which could be excessively hot and also high in toxic carbon monoxide content in the event of fire in progress above ground. This precaution of air recirculation (which could not safely be continued indefinitely) would be unnecessary if the shelter were provided with an appropriate carbon monoxide filter and with air cooling facilities.

Start Now

The difficulties of combating fire following nuclear explosion, particularly under fallout conditions, emphasize the importance of undertaking preventative measures now. Some of the most effective of these measures, such as the maintenance of general cleanliness and the safe enclosure of combustibles, are not only good wartime practice but also good peacetime practice. In view of the existing nearly billion dollar annual fire loss in the United States, and in view of the potentially extensive fire hazard in a nuclear war, the immediate execution of general fire protection measures would appear to merit the co-ordinated support of the Department of Defense, of the Federal Civil Defense Administration, and of the local communities involved throughout the nation.

Pyrophoric Metals—a Technical Mystery

By Richard B. Smith

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Pyrophoricity is, unfortunately, a property of several of the metals most widely used in atomic energy programs. Plutonium, uranium, thorium, zirconium, and hafnium are afflicted, as are magnesium, calcium, sodium, and potassium.

That this is no mere academic consideration is attested by the fact that half of AEC's 1955 monetary loss from property-damage incidents peculiar to nuclear activities stemmed from decontamination activities following spontaneous fires in radioactive metals.

Yet our understanding of pyrophoricity is very meager, quite inadequate to cope with the broad range of behavior exhibited by pyrophoric metals. Some of the phenomena observed and some possible mechanisms are discussed here; research now under way should fill in the picture considerably.

Although pyrophoric metal fires are infrequent, the cumulative experience in handling large quantities of these metals includes thousands of incidents. The vast bulk of these were minor spontaneous fires involving no property damage. However, a number are unusual incidents, the causes of which are difficult to explain rationally; a few involved fatal injuries and major property damage.

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The range of contrasts covered by such vagaries is indeed impressive. For example, massive (i.e. solid chunk rather than powdered) uranium will not normally ignite even when heated to its melting point — yet a case is known where a yeast-cake-size piece of massive uranium ignited spontaneously while resting on dry ice, and in another case a uranium specimen at room temperature spontaneously exploded. Spontaneous uranium fires have occurred under vacuum, under water, and under argon atmospheres. Spontaneous ignition and continued combustion of massive plutonium, uranium and thorium specimens have occurred in air at room temperature.

Metals do not ignite at consistent temperatures when heated in air. Metallic uranium, for example, can ignite spontaneously in air at room temperature when in the form of fine powders, but massive metal will not normally ignite even when heated to its melting point.

Comparison with Flammable Liquids

At the risk of oversimplification, a comparison with flammable liquid combustion is helpful in obtaining a better understanding of observed vagaries in metal fire and explosion properties.

Flammable vapor-air mixtures burn only when the concentration of vapor is between the lower and upper explosive limits. It is important to note that actual combustion involves an air-flammable-*vapor* reaction and *not* an air-flammable-*liquid* reaction. Experiments indicate that free burning of metals in air takes place at temperatures well above the metal melting point, at which temperatures the metal *vapor* pressure is well within a range comparable with that of flammable liquids undergoing combustion.

Recent tests have established that free unrestricted burning of magnesium takes place when the metal is approximately at its boiling point. This is known to be similarly the case, at the surface, where combustion of ordinary flammable liquids is involved.

In the case of pyrophoric metals, the surface is relatively rapidly cooled by conduction of heat to subsurface levels at a rate far greater than can take place between quiescent layers of normal flammable liquids. This ability to dissipate heat accounts in large measure for the difficulty in obtaining and sustaining combustion of such specimens without continued external application of heat. In view of the extremely high temperatures required for massive metal combustion, plus the fact that heat-radiation losses take place at a rate proportional to the fourth power of the temperature, the rarity of massive-metal fires is not surprising.

Massive-Metal Combustion

Spontaneous ignition of any massive pyrophoric metal is very rare. However, it has occurred in air at room temperatures in the case of plutonium, uranium and thorium with initial metal temperatures ranging from that of dry ice to red heat. Witnesses generally agree that these incidents are accompanied by slow but noticeable flaking off of the metal surface with sporadic emanation of localized sparking.

From these observations it is apparent that combustion of abnormally pyrophoric massive metals includes a "built-in" mechanism for converting a solid metal surface into an extremely fine, brittle, and chemically reactive powder, and that this mechanism is accelerated during auto-oxidation of the powder. Since ignition of massive metal has occurred at quite low temperatures, combustion in air of the surface powder must involve a highly exothermic reaction that more than offsets the heat loss from the metal surface. Thus, a basic mechanism contributing to ultimate burning of massive metal must involve both physical aspects (e.g., stress, brittleness, cracks, voids, etc.) and chemical aspects (initiating and secondary combustion).

Powder Combustion

The large difference in observed pyrophoricity of metal powders and massive metal proceeds from differences in secondary factors influencing combustion efficiency, rather than from any basic difference in the reaction mechanisms involved.

Metal powders possess a much greater surface area on which to generate heat, have a much smaller mass of metal in which to dissipate this heat, and have a much smaller percentage of total surface area available for loss of heat by radiation to external surroundings. All of these factors combine to increase the probability of metal combustion.

Effect of Mass

Unlike solid metal (in which heat can be internally transferred by the relatively efficient process of direct heat conduction), escape of any heat from within metal powders must largely take place by radiation through multiple insulating layers of air. Thus, accumulation of heat generated within metal powders by slow oxidation becomes increasingly probable with increasing size of the powder mass and with decreasing particle size.

Several interesting observations have been made of the effect of powder mass on pyrophoricity. Dust obtained by filing a zirconium-titanium alloy never ignited when dispersed over a bench, but always ignited spontaneously whenever small layers were accumulated. Zirconium powder dispersed over a red hot plate slowly oxidized, while a layer of the same powder thrown on the same plate immediately ignited and burned violently. Small layers of very fine uranium powder under water appear inert, while larger amounts tend to "ball up" following which spontaneous ignition is virtually certain.

The foregoing and other reported work suggest that for a metal powder of particular particle size there exists a definite minimum quantity of metal that must be exceeded for spontaneous ignition. Following the same line of reasoning, any metal capable of reacting exothermically with oxygen should also be capable of spontaneously igniting in air if the metal is sufficiently finely divided and if a sufficient quantity is present. Experimental work tends to confirm this suspicion for a series of metals (including iron, copper, and tungsten).

In many respects spontaneous ignition of metal powders is similar to spontaneous ignition of oily rags, while self-sustaining burning of massive metal is more nearly comparable to burning of ordinary flammable liquids and solids.

Powder Explosions

In general, the combustion in air of flammable vapors generates much less heat but a much greater volume of gases than does combustion of powdered pyrophoric metals. Since explosion pressure is roughly proportional to the product of the heat generated and the ultimate gas volume, an increase in explosion pressure is expected if the metals tested contain dissolved gases (notably hydrogen). Comparison of air-metal and air-metal-hydride dust explosion tests tends to confirm this suspicion. Maximum explosion pressures attainable upon detonation of air-powdered-metal mixtures are generally about equal to the maximum attainable by detonation of flammable-vapor-air mixtures.

Vapor or powdered-metal explosion pressures obviously vary with the materials involved, the ratio of mixture components, and the initial pressure. With initial mixtures at optimum proportions and atmospheric pressure, maximum explosion pressures are roughly 0–150 pounds per square inch gauge.

Effect of Particle Size

Qualitatively, the ease of ignition and explosion pressures attainable with metal dusts decrease rapidly with increasing particle size. The maximum particle size that will just support combustion following dispersion in air has

not been adequately investigated. The amount of energy required to initiate explosion of fine metal powders dispersed in air is often surprisingly low. In some cases the energy involved in dispersing the powder is sufficient to initiate spontaneous explosions.

Oxides Reduce Pyrophoricity

Although pyrophoric metals burn in oxygen, the pyrophoricity of many metals, e.g., uranium, can often be dramatically reduced, using oxygen. As an example, finely divided iron powder, prepared by hydrogen reduction of iron formate, will often ignite when first exposed to air. If, however, after preparing such powders, the hydrogen is replaced with an inert gas into which small amounts of dry oxygen are slowly fed while the furnace is being cooled to room temperatures, an iron powder is obtained that may be handled in air without ignition. A similar commercial process reduces pyrophoricity of highly porous thorium and zirconium sponge produced by the Kroll process.

The ability of oxide coatings to reduce apparent metal pyrophoricity varies considerably among different metals and even among specimens of the same metal. Both the physical and chemical properties of oxide coatings may change markedly with increasing temperatures. Some metals such as thorium and zirconium are capable of dissolving large quantities of surface oxides when heated above phase transformation temperatures, while other metals such as aluminum and uranium do not absorb significant quantities of surface oxides even when heated to their melting points.

Several investigators, while admitting that it does not make sense from a thermodynamic viewpoint, have found by test that zirconium powders containing up to 25 per cent oxide are more readily ignited than similar powders relatively free of oxides. The role played by surface oxides in the metal pyrophoricity picture is obviously important, complex, often erratic, and confusing.

Much information is available in the chemical literature on the oxidation of metals by oxygen, air, and water. Much is also known about the effects of oxide films on metal oxidation rates. The amount of heat liberated from combustion of specific metals can be accurately predicted, as can many factors influencing the probability of a reaction (such as temperature, pressure, etc.).

Despite this profusion of information, very little is known about the specific sequence of physical and chemical steps occurring during metal burning. Even less is known about reaction-rate variables during intermediate steps preceding and during metal combustion. This is particularly true when moisture and metal contaminants are involved.

The study of many unusual pyrophoric-metal incidents indicates apparently several independent mechanisms may contribute to metal pyrophoricity, and that surface oxides, stress, moisture, and contaminants are major facets deserving evaluation.

Moisture Increases Pyrophoricity

Metal pyrophoricity is strongly influenced by moisture. Metals such as sodium and potassium can react violently with water, as is well known. In the case of uranium, the high-temperature reaction with steam is much more violent than with oxygen.

Studies have indicated that the reaction between some metals (e.g., powdered aluminum or magnesium) and water is theoretically capable of producing a slightly more violent explosion than nitroglycerin or TNT. Russian scientists reported close-to-theoretical energy releases during tests aimed at preliminary evaluation of the use of water-metal reactions as high-explosives.

Many methods are known for inducing water-metal explosions. A few violent water-metal explosions have accidentally occurred in industry (notably during arc melting of titanium in

water-cooled crucibles). However, the rarity of such occurrences suggests that explosions of this type are only attainable under a very narrow set of conditions. That they can occur at all, however, justifies current AEC research.

Two recent reports provide strong circumstantial evidence that pyrophoricity of uranium and zirconium can sometimes be very materially increased by prior quiescent exposure to moisture at room temperature. Research is currently under way to determine the mechanism by which metal surfaces are pyrophorically influenced by water.

Stress Increases Pyrophoricity

There exists fragmentary but impressive evidence that pyrophoricity is increased when the metal is under stress. This stress can be physical or chemical. Uranium lathe chips, for example, appear to be very much more susceptible to spontaneous ignition than annealed metal of the same dimensions in sheet form. Several incidents suggest a connection between stress and metal-surface explosions in nitric acid. Sudden release of elastic strain can, under suitable conditions, cause adiabatic heating of metallic titanium fragments to their ignition temperature in air.

That pyrophoricity is increased by metal brittleness would be expected. For example, brittle alloys are used in lighter flints.

Sodium-potassium and titanium-zirconium alloys are more pyrophoric and have lower melting points than the pure constituent metals. This suggests that metal contaminants that lower melting points can, in some cases, add to metal pyrophoricity.

Sheet zirconium has ignited while under nitric acid when the sheet accidentally touched the graphite container. This suggests that surface contaminants can (in part through electrolytic effects) substantially alter metal pyrophoricity.

Significance of Hydrogen

The metal fire and explosion vagaries studied covered a wide range of temperatures, metal purities, atmospheres, surface-to-mass-ratios, etc. The only factor that appeared to be commonly involved in all of these incidents was hydrogen, i.e., all of the metals involved had either been made by hydride decomposition (and could therefore be suspected of retaining some hydrogen) or had at some time been exposed to water in some form.

The evidence of the significance of hydrogen was often dramatic. Thus, uranium chips often ignited in moist air but seemed nonpyrophoric in dry air. Metal spontaneously ignited (sometimes even in the absence of air) after prolonged storage under moist argon or water. Hydrogen concentrations on machined uranium surfaces sometimes ranged up to 50 times the published room temperature solubility of hydrogen in uranium. Brittle, pyrophoric uranium hydride has been identified following uranium exposure to water, etc.

While it is known that hydrogen on and below the metal surface is not the sole cause of pyrophoric anomalies, it is reasonably certain that it is a major common contributing cause. The various mechanisms by which hydrogen derived from water can enter and migrate within a metal are of less immediate interest than the ultimate effect of such hydrogen on pyrophoricity and the fate of the oxygen left after hydrogen removal from water.

It is thought that the principal effects of hydrogen on metal pyrophoricity include increasing internal stress, promoting metal surface fragmentation (in part through effects on brittleness, accentuation of grain boundary defects, and through subsurface gas evolution under heat), and reduction of surface-oxide protection of the metal.

Moesel's Theory

According to a theory proposed by F. C. Moesel, three possible reactions

occur: (a) metal plus moisture form metal hydride and hydrogen peroxide; (b) metal plus oxygen, in the presence of moisture, form metal oxide and additional peroxide; (c) metal plus hydrogen peroxide form metal peroxide or at least associate with each other by physical adsorption or absorption, which makes this reaction imminent. A metal fire in the absence of air would be the reaction of metal peroxide (or metal and hydrogen peroxide) with adjacent metal to form metal oxide with a liberation of heat. With a sufficient buildup in metal peroxide concentration, this reaction could be explosive. In the presence of air, the dispersion resulting from the primary explosion would result in a secondary explosion involving the oxidation of not only the earlier formed metal hydride, but also of the residual metal in the dispersed particles.

The general theory involved in spontaneous ignition of metal powders has been previously discussed. However, a number of incidents show that moist metal powders can, under some conditions, literally explode (either in the presence or absence of air), instead of simply igniting and quiescently burning. Mixed hydride and peroxide on the metal surface is one of several possible high-energy sources capable of spontaneously and very rapidly raising powder temperatures to a high degree.

In the discussion of massive-metal pyrophoricity theories, several mechanisms were covered relative to fragmentizing of heated metal surfaces. The same principles are thought to be even more applicable to metal powders.

Finally, the Russian experimenters obtained high-energy water-metal explosions under conditions comparable to hot fragmentized powdered metal. Thus, both theory and experience justify considerable precautions when handling or heating moist, finely divided powders with the degree of concern increasing with increasing quantities and decreasing average particle size.

Experience and experiments have shown that when water contacts molten pyrophoric metals, rapid generation of steam is, under quite narrow conditions, occasionally accompanied by violently explosive water-metal reactions. In the case of high-melting-point pyrophoric metals, experiments have shown that when water-metal explosions are attained, only a small percentage of the molten metal reacts with water. From this fact it can be assumed that the critical conditions are disrupted during the explosion. It is thought that during that very brief interval in which the very-high-temperature liquid metal can remain in contact with water, a combination of mechanical and exothermic chemical forces cause rapid spewing of finely divided and exceedingly hot metal particles into water. The basic mechanism involved in liquid metal-water explosions is viewed as being very similar to, but more severe than, the moist-metal-powder explosions.

Fires and Fire Losses Classified, 1956

Editor's Note: During recent years NFPA members have called attention to instances where certain parts of this article, notably Table VI, have been taken out of context and misused in advertisements and otherwise. Readers are reminded that material published in the QUARTERLY is copyrighted and may not be reproduced in whole or in part without written permission from the Association. The article in its entirety will be available from the Association in pamphlet form early in October.

There were approximately 1,940,150 fires of all types in the United States in 1956 causing a loss of $1,231,576,000. According to estimates compiled by the National Fire Protection Association, the 1956 loss was an increase of $90,808,000 over the $1,140,768,000 estimated loss of 1955. The $32,000,000 increase in the "large loss building fire" losses,* and the $40,000,000 increase in aircraft losses were the principal factors responsible for this jump to the largest annual fire loss on record.

Building fires in the United States in 1956 totalled 824,400 and caused $1,016,000,000 damage. An additional 1,115,750 fires not involving buildings — aircraft, motor vehicles, forest, ships, rubbish, grass fires, etc.—accounted for an estimated $215,576,000. Building fire estimates for 1955, reported in the October 1956 QUARTERLY showed 811,800 fires with $943,551,000 loss.

The number of building fires for 1956 has increased 1.6 per cent over 1955 figures, while the loss of 1956 is 7.7 per cent more than the previous year.

The data from which Tables I to IV were compiled were obtained from 14 state fire marshals' reports for the year 1956 or the closest fiscal year thereto. Because of the advancement of the mailing date of the October QUARTERLY some state reports, which in past years had been used, did not arrive in time to be included this year.

*See "Large Loss Fires of 1956" published in the April 1957 QUARTERLY.

While the methods of reporting and tabulating fire loss figures differ from state to state, the volume of statistics from the 14 typical states chosen, representing all sections of the country and including both primarily agricultural and industrial states, is sufficiently large to indicate the relative distribution of fires and fire losses. Table I shows the number of fires by occupancy in 12 states and Table II the loss by occupancy in 11 states. Tables III and IV list the number of fires and loss by cause in 13 and 10 states respectively.

Tables V and VI, showing the nation-wide distribution of fires and losses by occupancy and cause, are based primarily on typical state experience enumerated in Tables I to IV. Table VII summarizes statistics from all state reports received.

Various sources have furnished figures for items in Table V. Railroad losses were furnished by the Association of American Railroads, Fire Protection and Insurance Section. Statistics on aircraft fires were compiled by the NFPA Committee on Aviation and Airport Fire Protection. Motor vehicle data are based on a recent survey of 576 U. S. cities (Fire Record of Cities, April, 1957 QUARTERLY. The estimate of the number of forest fires was compiled by the Forest Service of the U. S. Department of Agriculture.

As will be seen in Table VII, the 15 states with a population of 38,947,000

(Continued on page 149)

TABLE I. Number of Fires by Occupancies in Twelve States — 1956

	Conn.[4]	Iowa	Kansas	Louisiana	Minn.[1]	Nebraska	N. H.	N. Dak.[2,3]	Ohio	Oregon[3]	S. Dak.[4]	W. Vir.[5]	Totals
I. Public Buildings													
Government buildings	1	6	...	...	...	2	1	18	...	25	2	...	55
Hospitals, institutions	1	14	5	34	12	2	2	...	28	...	...	2	100
Schools and colleges	20	26	12	41	21	21	4	4	50	54	8	11	272
Churches	8	16	19	47	13	5	7	13	51	27	2	7	215
Theatres, including motion pictures	5	2	1	20	8	2	4	...	18	6	2	...	68
Amusement, halls	11	17	9	...	24	37	14	...	52	...	2	4	170
II. Residential													
Hotels	26	40	35	335i	71	17	14	28	176	270i	29g	7	1,048
Boarding and rooming houses	48	14	8a	...	3	...	12	...	...	...	...	...	85
Apartments	208	186	89	...	162e	76e	42	...	1,426e	...	20	38	2,247
Dwellings	996	1,567	1,731	4,167	1,144	671	779	407f	5,558	10,838f	486	573	28,917
Motels, tourist cabins	...	6	13	...	4	9	1	...	...	...	...	...	33
III. Mercantile													
Offices, banks	22	30	31	...	32	6	2	...	116	...	3	9	251
Restaurants, taverns	67	71	54	...	69	24	14	...	...	87	11	22	419
Miscellaneous mercantiles	158	194	279	427	239	74	63	93	563	494	75h	49	2,708
Warehouses	24	34	62	93	70	13	1	11	182	32	...	6	528
IV. Manufacturing													
Metal workers	8	13	18	19	12	4	6	1	...	28	4	2	115
Woodworkers	2	16	3	29	...	...	16	3	...	151	...	...	220
Grain mills, elevators	...	11	19	11	26	17	4	31	...	8	8	...	135
Food processing	...	4	12	22	...	6	1	3	...	28	2	2	80
Bakeries	6	6	3	...	10	...	1	...	...	4	3	1	34
Textile workers	3	...	1	70	...	...	...	1	...	3	...	...	78
Printing	3	8	1	...	...	4	4	...	...	7	3	2	32
Laundries	7	4	16b	...	7	7b	3	...	16	21b	1	4b	86
Cleaners, tailors	5	11	...	...	14	...	1	...	27	...	...	...	58
Miscellaneous manufacturing	102	48	9	21	102	12	42	8	384	48	5	19	800
V. Miscellaneous													
Barns	143	285	442c	175c	135	278c	38	226c	447	152c	105	33	2,459
Outbuildings	...	438	...	...	519	157	127	...	542	...	13	15	1,811
Lumber and coal yards	2	10	9	15	10	3	3	2	27	...	5	9	95
Piers, including shipyards	1	...	2	...	...	...	...	...	...	...	...	...	3
Railroad property, inc. rolling stock	...	25	14	...	16	9	1	...	...	...	4	1	70
Bulk oil storage, refineries	1	...	9	45	1	9	...	5	...	26	...	1	97
Garages	146	34	44d	17	33d	35	9	31	628d	23	58d	33	1,091
Filling stations	11	20	...	...	...	...	8	...	...	...	...	6	45
Power plants, pump houses	...	10	2	36	7	8	3	2	...	18	4	1	91
Creameries, and dairies	...	3	1	...	20	6	2	...	...	8	1	...	41
Miscellaneous structures	10	411	3	88	44	6	3	5	1,200	14	1	42	1,827
VI. Other Than Building Fires													
Aircraft	...	...	...	...	...	...	...	...	...	...	...	...	...
Motor vehicles	154	559	419	580	151	203	...	...	2,347	729	157	41	5,340
Forest fires	...	...	...	...	...	...	...	...	...	...	...	...	...
Rubbish, grass, brush	...	32	...	...	...	125	...	...	...	...	127	...	284
Miscellaneous	276	284	1	...	72	26	...	...	72	5	13	16	765
Grand Total	2,475	4,455	3,376	6,292	3,051	1,874	1,232	892	13,910	13,106	1,154	956	52,773

[1] No losses less than $25.
[2] Fiscal year ended June 30, 1956.
[3] Insured losses only.
[4] Fiscal year ended June 30, 1957.
[5] No losses less than $50.

a. Includes fraternity and sorority houses.
b. Includes dry cleaners.
c. Includes all farm property.
d. Includes filling stations.
e. Includes rooming houses.
f. Includes apartments.
g. Includes restaurants.
h. Includes warehouses.
i. Includes motels, boarding houses and clubs.

[1] Fiscal year ended June 30, 1957.
[5] No losses less than $50.

d. Includes filling stations.
e. Includes rooming houses.

i. Includes motels, boarding houses and clubs.

TABLE II. Fire Losses by Occupancies in Eleven States — 1956

Occupancies	Conn.[4]	Iowa	Kansas	Louisiana	Minnesota[1]	Nebraska	N. Dak.[2,3]	Ohio	Oregon[3]	S. Dak.[4]	W. Va.[5]	Totals
I. Public Buildings												
Government buildings	$ 807	$ 5,782	.....	.....	.....	$ 10,300	$ 36,048	.....	$ 13,549	$ 2,000	.....	$ 68,486
Hospitals, institutions	625	18,506	$ 1,434	$ 47,276	$ 131,475	26,066	.....	$ 18,040	.....	.....	1,500	244,922
Schools and colleges	758,761	336,656	98,785	294,134	195,277	456,716	2,350	429,495	475,224	86,864	1,864,622	4,998,884
Churches	3,734,211	118,935	125,483	143,475	131,243	43,223	12,788	1,110,288	10,671	5,550	28,790	5,464,657
Theatres, including motion pictures	1,950	112,875	75	77,997	61,300	4,125	.....	16,520	25,879	18,784	.....	319,505
Amusement, halls	201,337	155,830	87,840	.....	147,894	280,678	.....	267,176	.....	8,350	20,505	1,169,610
II. Residential												
Hotels	19,437	34,864	80,756	312,884i	359,320	12,833	54,940	146,252	374,603i	49,794g	34,600	1,480,283
Boarding and rooming houses	40,421	7,973	15,865a	.....	70,890	.....	.....	.....	.....	.....	.....	135,149
Apartments	421,623	180,891	51,005	.....	353,010e	75,008e	.....	1,110,227e	.....	16,268	294,528	2,502,560
Dwellings	2,415,096	2,774,227	1,442,201	4,067,897	2,415,688	1,229,645	452,277f	7,312,407	5,107,381f	471,107	1,820,001	29,507,927
Motels, tourist cabins	.....	6,271	48,665	.....	12,650	9,452	.....	.....	.....	.....	.....	77,038
III. Mercantile												
Offices, banks	55,453	157,374	117,797	.....	70,755	53,245	.....	220,777	.....	1,840	512,025	1,189,266
Restaurants, taverns	256,603	184,301	68,545	.....	418,554	52,521	.....	.....	235,132	20,621	266,150	1,502,427
Miscellaneous mercantiles	805,447	1,644,940	1,171,696	1,651,277	3,453,017	887,071	231,772	3,099,031	1,592,558	475,875h	956,235	15,968,919
Warehouses	152,694	1,657,536	948,210	1,287,986	386,804	706,959	34,413	1,359,625	246,801	.....	46,490	6,827,518
IV. Manufacturing												
Metal workers	5,290	30,404	742,065	35,682	17,450	15,685	4,253	.....	442,660	24,288	1,600	1,319,377
Woodworkers	80,306	7,265	26,550	532,979	.....	.....	3,606	.....	2,401,895	.....	.....	3,052,601
Grain mills, elevators	.....	375,341	194,681	170,138	618,966	145,830	470,815	.....	32,229	307,740	.....	2,315,740
Food processing	.....	140,403	54,520	608,465	.....	12,025	6,766	.....	694,094	565	3,200	1,520,038
Bakeries	15,500	2,697	265	.....	15,434	.....	.....	.....	3,168	4,587	500	42,151
Textile workers	44,000	.....	29,500	284,704	.....	.....	998	.....	724	.....	.....	359,926
Printing	2,800	26,200	10	.....	.....	60,865	.....	.....	3,752	12,025	25,700	131,352
Laundries	10,097	5,697	120,011b	.....	24,275	3,434b	.....	89,125	30,711b	200	2,650b	286,200
Cleaners, tailors	8,885	5,828	.....	.....	123,955	.....	.....	13,790	.....	.....	.....	152,458
Miscellaneous manufacturing	653,525	665,851	14,600	1,613,031	1,139,168	39,293	17,742	4,917,428	376,390	23,949	149,329	9,610,306
V. Miscellaneous												
Barns	762,228	1,482,228	1,194,277c	358,555c	640,200	716,725c	442,835c	2,888,811	422,747c	217,507	306,791	9,432,904
Outbuildings	.....	399,797	.....	.....	623,045	152,723	.....	233,083	.....	12,102	23,050	1,443,800
Lumber and coal yards	2,696	198,014	581,700	213,885	251,238	114,100	2,147	38,555	.....	371	539,800	1,942,506
Piers, including shipyards	300	.....	250	.....	.....	.....	.....	.....	.....	.....	.....	550
Railroad property, inc. rolling stock	.....	19,793	22,973	.....	463,540	20,275	.....	.....	6,578	150	533,309	
Bulk oil storage refineries	2,000	.....	25,445	2,185,212	40,000	12,225	28,536	.....	132,164	.....	500	2,426,082
Garages	288,535	318,725	130,804d	42,884	168,020d	198,238	125,127	1,150,855d	47,189	171,131d	532,480	3,173,988
Filling stations	52,620	16,724	.....	.....	.....	.....	.....	.....	.....	.....	4,800	74,144
Power plants, pump houses	.....	166,900	575	129,472	109,400	1,603	1,880	.....	218,553	948	2,821	632,152
Creameries and dairies	.....	201,406	75	.....	105,371	18,650	.....	.....	2,124	125	.....	327,751
Miscellaneous structures	31,265	484,452	1,150	439,902	635,077	22,114	1,898	4,107,822	1,260,872	2,200	321,143	7,307,895
VI. Other Than Building Fires												
Aircraft	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Motor vehicles	91,641	155,212	155,675	271,963	163,991	229,631	.....	1,186,554	113,107	63,879	181,726	2,613,379
Forest fires	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Rubbish, grass, brush	.....	12,689	.....	.....	.....	71,028	.....	.....	.....	59,369	.....	143,086
Miscellaneous	1,557,837	437,648	300	.....	91,065	23,391	.....	4,845	119,733	8,980	161,973	2,405,772
Grand Total	$12,473,990	$12,550,235	$7,553,783	$14,769,798	$13,438,072	$5,705,677	$1,931,191	$29,720,706	$14,383,910	$2,073,597	$8,103,659	$122,704,618

[1] No losses less than $25.
[2] Fiscal year ended June 30, 1956.
[3] Insured losses only.
[4] Fiscal year ended June 30, 1957.
[5] No losses less than $50.

a. Includes fraternity and sorority houses.
b. Includes dry cleaners.
c. Includes all farm property.
d. Includes filling stations.
e. Includes rooming houses.

f. Includes apartments.
g. Includes restaurants.
h. Includes warehouses.
i. Includes motels, boarding houses and clubs.

TABLE III. Number of Fires by Causes in Thirteen States — 1956

Causes	Conn.[1]	Iowa	Kansas	La.	Mich.	Nebr.	N. H.	N.Dak.[2,3]	Ohio	Ore.[3]	R. I.[4]	S. Dak.[1]	W. Vir.[5]	Totals
Chimneys, flues — defective or overheated	76	133	57	77	1,546	71	140	45	489	790	42	35	70	3,571
Sparks on roof	12	93	23	...	622	...	...	...	270	170	...	...	...	1,190
Defective or overheated heating and cooking equipment														
Oil-fired equipment	176	95	...	156	2,605	...	80	40	...	...	86	37	13	3,288
Gas-fired equipment	...	23	...	229	...	...	...	43	...	...	...	...	6	301
Other and unknown	119	201	237	44	3,900	168	156	33	925	958	97	125	70	7,033
Rubbish, ignition unknown	69	424	290	183	7,501	156	24	...	477	58	35	72	1	9,290
Combustibles near heaters	5	91	...	...	...	15	15	...	...	...	...	...	29	155
Open lights, flames, sparks	49	66	74	619	420	63	18	83	300	84	75	64	12	1,927
Hot ashes, coals	4	24	58	...	244	7	3	...	86	1,077	4	3	2	1,512
Smoking and matches	442	439	331	898	4,405	176	179	92	2,608	3,313	83	95	88	13,149
Children and matches	164	172	...	...	2,275	103	50	...	859	...	39	59	...	3,721
Electrical, fixed services, fires due to misuse or faulty wiring, equipment	204	287	397	935a	2,105	232	145	116a	2,463	1,187	114	131	137	8,453
Electrical, power consuming appliances	130	254	16	...	2,906	95	91	...	403	1,421	3	77	7	5,403
Flammable liquids, misuse of including vapor explosions, grease, tar, etc.	68	94	202	...	443	152	83	...	774	2,008	57	34	36	4,041
Flammable liquid appliances, inc'l lamps, blow torches, salamanders, etc.	42	27	...	...	...	2	4	...	...	...	...	24	7	106
Torches, welding and cutting	...	51	...	35	...	24	15	7	49	...	...	11	3	195
Gas and appliances, including gas explosions	...	13	60	...	573	20	4	...	180	...	5	44	16	915
Spontaneous ignition	32	83	21	38	2,249	56	23	14	251	77	15	45	22	2,926
Lightning	41	187	87	511	924	89	78	51	429	173	8	46	24	2,648
Thawing pipes	3	17	...	...	111	10	4	...	...	...	...	1	3	149
Sparks from machinery, friction	...	16	7	25	...	11	...	5	...	23	...	...	7	94
Incendiary, suspicious	100	32	31	75	1,036	31	25	3	217	54	52	6	27	1,689
Miscellaneous	399	485	164	199	19,216	36	28	101	1,500	44	186	108	28	22,494
Unknown	304	729	1,076	1,762	6,229	312	38	213	1,251	963	233	116	270	13,496
Explosions, miscellaneous and unclassified	10	...	27	...	...	4	...	...	...	88	...	4	11	144
Exposure	26	419	218	506	...	41	29	46	379	528	20	17	67	2,296
Totals	2,475	4,455	3,376	6,292	59,310	1,874	1,232	892	13,910	13,106	1,154	1,154	956	110,186

[1] Fiscal year ended June 30, 1957.
[2] Fiscal year ended June 30, 1956.
[3] Insured losses only.
[4] Fiscal year ended Sept. 30, 1956.
[5] No losses less than $50.

a. Includes electrical power consuming appliances.

TABLE IV. Fire Losses by Causes in Ten States — 1956

Causes	Connecticut[1]	Iowa	Kansas	Louisiana	Nebraska	N. Dakota[2,3]	Ohio	Oregon[3]	S. Dakota[1]	W. Virginia[4]	Totals
Chimneys, flues — defective or overheated	$ 184,689	$ 195,919	$ 75,233	$ 77,681	$ 105,348	$ 64,438	$ 855,911	$ 591,154	$ 54,279	$ 342,197	$ 2,546,849
Sparks on roof	13,033	131,553	114,036	.....	.....	.....	294,395	124,952	.....	.....	677,969
Defective or overheated heating and cooking equipment —											
Oil-fired equipment	480,604	347,096	.....	337,146	.....	67,145	.....	.....	40,486	66,775	1,339,252
Gas-fired equipment	.....	13,973	.....	326,364	.....	128,388	.....	.....	.....	7,915	476,640
Other and unknown	463,548	443,174	343,161	39,498	361,194	48,582	2,169,861	603,904	100,470	293,114	4,866,506
Rubbish, ignition unknown	122,497	273,098	168,316	153,185	145,896	.....	245,513	58,541	62,787	1,400	1,231,233
Combustible near heaters	3,637	139,697	.....	.....	26,810	.....	.....	.....	.....	221,389	391,533
Open lights, flames, sparks	67,003	77,650	57,051	1,089,621	127,937	107,579	469,317	23,397	68,870	55,031	2,143,456
Hot ashes, coals	4,695	4,075	37,820	.....	6,287	.....	73,248	397,750	2,630	4,300	530,805
Smoking and matches	725,908	344,838	107,991	454,025	180,231	70,540	1,422,206	555,499	46,230	1,633,957	5,541,425
Children and matches	183,951	100,440	.....	.....	115,398	.....	706,559	.....	39,803	.....	1,146,151
Electrical, fixed services, fires due to misuse or faulty wiring, equipment	642,447	1,244,387	484,867	1,168,261a	1,026,130	327,640a	5,281,807	2,006,333	268,194	901,017	13,351,083
Electrical, power consuming appliances	151,621	156,634	4,105	.....	124,020	.....	1,119,195	384,510	162,487	20,950	2,123,522
Flammable liquids, misuse of including vapor explosions, grease, tar, etc.	140,558	119,116	303,389	.....	252,871	.....	1,098,758	786,792	18,551	234,624	2,954,659
Flammable liquid appliances, inc'l lamps, blow torches, salamanders, etc.	53,548	32,653	.....	.....	250	.....	.....	.....	57,396	122,800	266,647
Torches, welding and cutting	.....	204,711	.....	1,528,523	41,651	7,501	66,880	.....	118,290	85,600	2,053,156
Gas and appliances, including gas explosions	.....	192,736	90,221	.....	54,980	.....	413,506	.....	146,234	41,935	939,612
Spontaneous ignition	266,452	248,852	35,058	226,679	143,288	30,614	1,071,596	812,175	118,912	127,952	3,081,578
Lightning	117,611	771,384	317,582	430,980	173,026	93,365	1,371,637	168,896	50,138	162,053	3,656,672
Thawing pipes	12,025	9,565	.....	.....	10,637	.....	.....	.....	20	4,400	36,647
Sparks from machinery, friction	.....	29,313	3,096	114,808	13,975	10,727	.....	137,765	.....	17,800	327,484
Incendiary, suspicious	344,833	29,117	57,522	130,074	113,878	5,748	910,120	182,247	9,230	168,646	1,951,415
Miscellaneous	1,346,826	651,387	135,624	360,565	58,160	164,152	1,994,943	87,546	64,775	110,166	4,974,144
Unknown	6,969,315	5,369,776	4,932,832	7,883,422	2,442,410	732,950	9,609,811	6,884,355	593,812	2,507,621	47,926,304
Explosions, miscellaneous and unclassified	62,916	.....	60,147	.....	29,900	.....	.....	288,840	19,783	125,175	586,761
Exposure	116,273	1,419,091	225,732	448,966	151,400	71,822	545,443	289,254	30,220	846,842	4,145,043
Totals	$12,473,990	$12,550,235	$7,553,783	$14,769,798	$5,705,677	$1,931,191	$29,720,706	$14,383,910	$2,073,597	$8,103,659	$109,266,546

[1] Fiscal year ended June 30, 1957.
[2] Fiscal year ended June 30, 1956.
[3] Insured losses only.
[4] No losses less than $50.

a. Includes electrical power consuming appliances.

Table V. Estimated Distribution of U. S. Fire Losses by Occupancies, 1956

These estimated figures are intended to show the relative order of magnitude of fire losses by occupancies, and while they are reasonable approximations based on the experience in typical states, they should not be taken as exact records for each class. As explained in the text, 100 per cent has been added in estimating the number of fires, and 33⅓ per cent has been added to the losses to cover unreported losses.

	No. of Fires		Losses	
I. Public Buildings				
Government buildings	1,700		$ 2,250,000	
Hospitals, institutions	1,600		5,254,000	
Schools and colleges	4,100		32,824,000	
Churches	3,200		20,855,000	
Theatres, including motion pictures	1,000		3,892,000	
Amusement, halls	3,400	15,000	13,367,000	$ 78,442,000
II. Residential				
Hotels	12,000		13,285,000	
Boarding and rooming houses	6,500		2,860,000	
Apartments	29,500		24,918,000	
Dwellings	523,500		260,000,000	
Motels, tourist cabins	1,900	573,400	2,130,000	303,193,000
III. Mercantile				
Offices, banks	8,000		8,587,000	
Restaurants, taverns	17,900		18,622,000	
Miscellaneous mercantiles	37,800		98,860,000	
Warehouses	7,100	70,800	58,287,000	184,356,000
IV. Manufacturing				
Metal workers	3,100		32,390,000	
Woodworkers	4,700		39,556,000	
Grain mills, elevators	4,100		36,600,000	
Food processing	2,500		9,580,000	
Bakeries	1,000		2,931,000	
Textile workers	7,500		9,221,000	
Printing	1,100		2,240,000	
Laundries	1,700		2,830,000	
Cleaners, tailors	1,600		1,910,000	
Miscellaneous manufacturing	11,000	38,300	70,239,000	207,497,000
V. Miscellaneous				
Barns	41,000		71,600,000	
Outbuildings	32,400		16,500,000	
Lumber and coal yards	1,500		18,855,000	
Piers, including shipyards	1,800		22,446,000	
Railroad property, inc. rolling stock	4,900		11,302,000	
Bulk oil storage, refineries	2,000		7,000,000	
Garages	15,100		25,473,000	
Filling stations	2,900		2,330,000	
Power plants, pump houses	2,500		2,130,000	
Creameries and dairies	1,600		6,060,000	
Miscellaneous structures	21,200	126,900	58,816,000	242,512,000
Total (Building Fires)		824,400		$1,016,000,000
VI. Other Than Building Fires				
Aircraft	250		130,000,000	
Motor vehicles	173,500		18,600,000	
Forest fires	143,500		42,305,000	
Rubbish, grass, brush	735,000			
Miscellaneous	63,500	1,115,750	24,671,000	215,576,000
Grand Total		1,940,150		$1,231,576,000

reported a total of 119,118 fires. Experience indicates that this is somewhat under half the actual number of fires in these states. Some states, for example, do not report fires with uninsured losses, others report only fires with losses in excess of $50.

To obtain national estimates of the number of fires by occupancy 100 per cent was added to the number reported by the twelve states shown in Table I. Making use of this figure and population ratios, the number of fires by occupancy in the United States was calculated. Further adjustments were made based upon other surveys of 1956 fire experience. Following a similar procedure with the state experience shown in Table III, national estimates of the numbers of fires by cause were obtained.

To obtain the estimated national fire loss by occupancy and cause, the population ratio was applied to the loss of the states shown in Tables II and IV. To account for losses not reported through the usual channels, 33⅓ per cent was added as in the previous years. Further adjustment was necessary in a few instances because of unusually large damage in individual fires.

Table VI. Estimated U. S. Building Fire Losses by Causes, 1956

These estimated figures are intended to show the relative order of magnitude of fire losses by causes, and to indicate year-to-year trends. While they are reasonable approximations based on the experience in typical states, they should not be taken as exact records for each class. These figures by themselves do not show the relative safety in utilization of various types of material, devices, fuels or services and should not be used for this purpose.

	No. of fires	Losses
Chimneys, flues — defective or overheated	35,000	$ 22,300,000
Sparks on roof	15,800	10,500,000
Defective or overheated heating and cooking equipment —		
Oil-fired equipment	50,700	36,500,000
Gas-fired equipment	9,800	12,800,000
Other and unknown	48,000	42,800,000
Rubbish, ignition unknown	57,000	11,100,000
Combustibles near heaters	15,900	10,600,000
Open lights, flames, sparks	18,500	18,800,000
Hot ashes, coals	16,300	9,900,000
Smoking and matches	127,000	69,100,000
Children and matches	34,500	15,900,000
Electrical, fixed services, fires due to misuse or faulty wiring, equipment	67,500	120,500,000
Electrical, power consuming appliances	38,700	21,800,000
Flammable liquids, misuse of including vapor explosions, grease, tar, etc.	43,500	38,500,000
Flammable liquid appliances, inc'l lamps, blow torches, salamanders, etc.	4,000	6,650,000
Torches, welding and cutting	4,300	16,400,000
Gas and appliances, including gas explosions	11,200	11,700,000
Spontaneous ignition	27,200	45,790,000
Lightning	45,200	35,540,000
Thawing pipes	2,900	2,920,000
Sparks from machinery, friction	3,500	5,400,000
Incendiary, suspicious	11,500	25,100,000
Miscellaneous	41,000	43,500,000
Unknown	67,400	320,000,000
Explosions, miscellaneous and unclassified	4,400	25,600,000
Exposure	23,600	36,300,000
TOTALS	824,400	$1,016,000,000

Table VII. Fires per 1000 Population and Fire Loss per Person for Fifteen States, 1956, as Reported by Fire Marshals

State	Population 1957 Est.	No. of Fires	Fires per 1000 pop.	Fire Loss	Fire Loss per Person
Connecticut[6]	2,256,000	2,475	1.10	$ 12,473,990	$5.54
Iowa	2,702,000	4,455	1.65	12,550,235	4.65
Kansas	2,123,000	3,376	1.59	7,553,783	3.55
Louisiana	3,036,000	6,292	2.07	14,769,798	4.87
Michigan	7,627,000	59,310	7.78	35,349,943	4.64
Minnesota[1]	3,266,000	3,051	0.93	13,438,072	4.12
Nebraska	1,423,000	1,874	1.32	5,705,677	4.01
New Hampshire	563,000	1,232	2.19	4,011,045	7.13
New Mexico	827,000	5,198	6.28	3,739,726	4.51
North Dakota[2,3]	660,000	892	1.33	1,931,191	2.93
Ohio	9,215,000	13,910	1.51	29,720,706	3.22
Oregon[3,4]	1,736,000	13,106	7.55	14,383,910	8.29
Rhode Island[5]	831,000	1,837	2.21	4,775,239	5.75
South Dakota[6]	700,000	1,154	1.65	2,073,597	2.96
West Virginia[7]	1,982,000	956	4.83	8,103,659	4.08
TOTALS	38,947,000	119,118	3.06	$170,580,571	$4.39

[1] No losses less than $25.
[2] Fiscal year ended June 30, 1956.
[3] Insured losses only.
[4] Actual losses when claims were made.
[5] Fiscal year ended Sept. 30, 1956.
[6] Fiscal year ended June 30, 1957.
[7] No losses less than $50.

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THE SKINNER CHUCK COMPANY NEW BRITAIN, CONN.

and SKINNER ELECTRIC VALVE DIVISION

gets better protection . . .

SAVES $12,500 A YEAR

by protecting its property *Automatically* with **ADT**

- Sprinkler Supervisory and Waterflow Alarm Service
- Aero Automatic Fire Detection and Alarm Service
- Heating and Industrial Process Supervisory Service

We strive in every way to maintain uninterrupted production, and for that reason sought the best available safeguards for our plant. Experience with ADT Automatic Protection has proved that it is superior to hourly patrols in keeping us safe from fire and other hazards, though it is considerably less costly. Our savings are approximately $12,500 a year.

Paul K. Rogers, Jr.
PRESIDENT

Quality is an important factor in the manufacture of Skinner chucks and Skinner electric valves. The firm likewise demands quality in the protection of its plant . . . a primary consideration in their selection of ADT *Automatic* Protection Services for existing buildings and two new wings now under construction.

The satisfaction expressed by Mr. Rogers is typical of the comment of thousands of business executives who know that ADT *Automatic* Services give better protection for property, profits and employees' jobs, and at less expense.

May we show you what ADT can do for you?

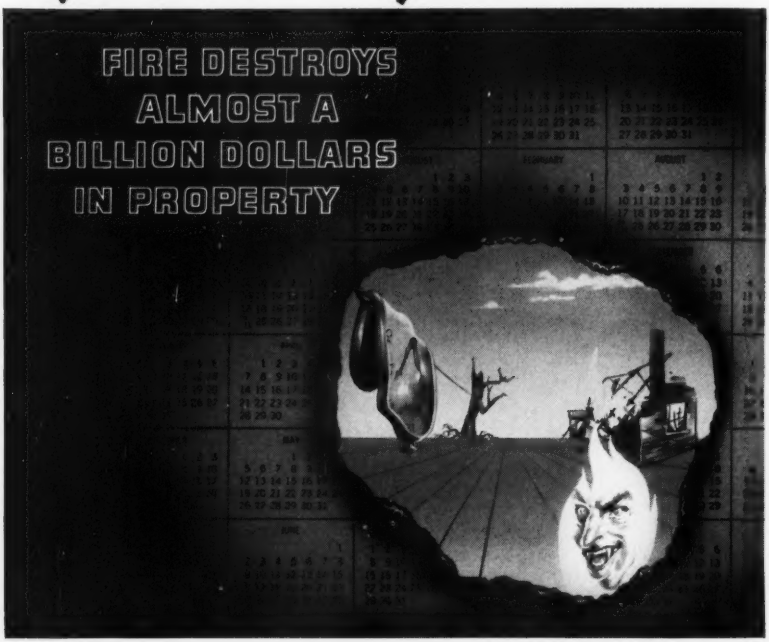
Whether your premises are new or old, sprinklered or unsprinklered, there is an ADT Automatic Protection Service to detect dangerous conditions and to notify fire, police or other protective forces immediately and *automatically*.

An ADT specialist will be glad to show you how combinations of automatic services can safeguard your property. Call if we are listed in your phone book; or write to our Executive Office.

ADT

Controlled Companies of
AMERICAN DISTRICT TELEGRAPH COMPANY
A NATIONWIDE ORGANIZATION
155 Sixth Avenue, New York 13, N. Y.

Year in ... Year out...



Fire is no respecter of clocks or calendars . . . people or property. Each year thousands of people die in fires . . . millions upon millions of dollars worth of property is consumed.

And most fires are the result of carelessness! That's why continuous fire prevention efforts all through the year are so necessary.

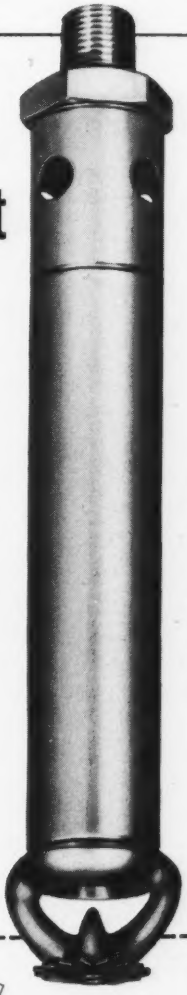
No one is more vitally interested in preventing fires — in homes, schools, churches, businesses, and industry — than the field representatives of our companies. They may be contacted through local insurance agents, and there is no charge for their services.

Make fire prevention a regular, year around part of your activities. Our representatives will welcome a chance to work with you.

Fire Insurance Division

ÆTNA CASUALTY and SURETY COMPANY
STANDARD FIRE INSURANCE COMPANY
Hartford, Connecticut
Affiliated with Ætna Life Insurance Company

New Rockwood FOAMwater Sprinklers blanket burning liquids faster



Here's a device that combines the features of the well-known Rockwood FogFOAM application with that of the proven Rockwood WaterFOG Sprinkler!

This new FOAMwater Sprinkler used in Rockwood Fixed Piping systems offers greater protection for such hazards as airplane hangars, storage facilities or processes where flammable liquid and material are involved.

With the new Rockwood FOAMwater Sprinkler, systems can be designed to apply FogFOAM, and apply water if the FOAM becomes exhausted. It can be used with Rate-of-Rise Control or manual control, and is designed for open head operation only.

Tested and listed by Underwriters' Laboratories, Inc., the unit after 20 minutes of running water from the system proved that the FOAM blanket was still satisfactory.

Write for full data on this latest fire protection from Rockwood.

ROCKWOOD SPRINKLER COMPANY

Engineers Water... to Cut Fire Losses

ROCKWOOD SPRINKLER COMPANY
2465 Harlow Street, Worcester 5, Mass.

Please send me additional information on Rockwood's FOAMwater Sprinklers.

Name.....

Title.....

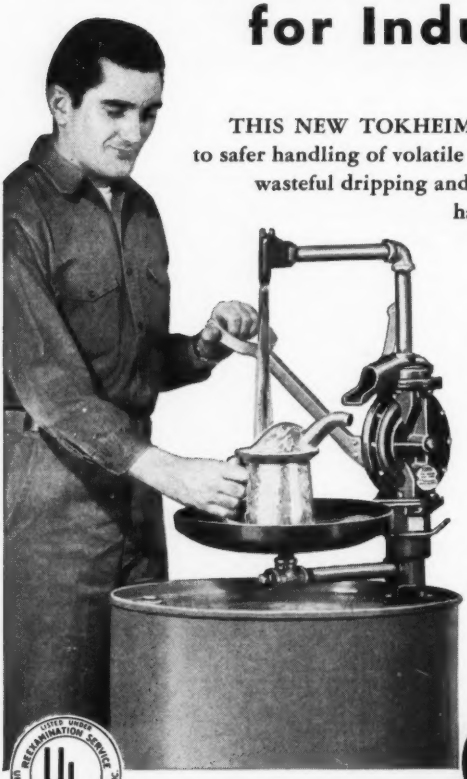
Company.....

Street.....

City.....*Zone*....*State*.....

SAFER

liquid handling for Industry



THIS NEW TOKHEIM HAND PUMP contributes to safer handling of volatile liquids wherever used. Stops wasteful dripping and slippery floors. Reduces fire hazard and accidents common to other methods of liquid transfer. Approved for handling petroleum liquids —ideal for many others. Available in 22 different models for 'most any use— from pipe lines to drums, or underground tanks, with hose or spout outlets. Order from your dealer, your oil company, or your Tokheim representative.

Write factory for literature.

QUALITY TOKHEIM HIGH VACUUM HAND PUMPS

General Products Division

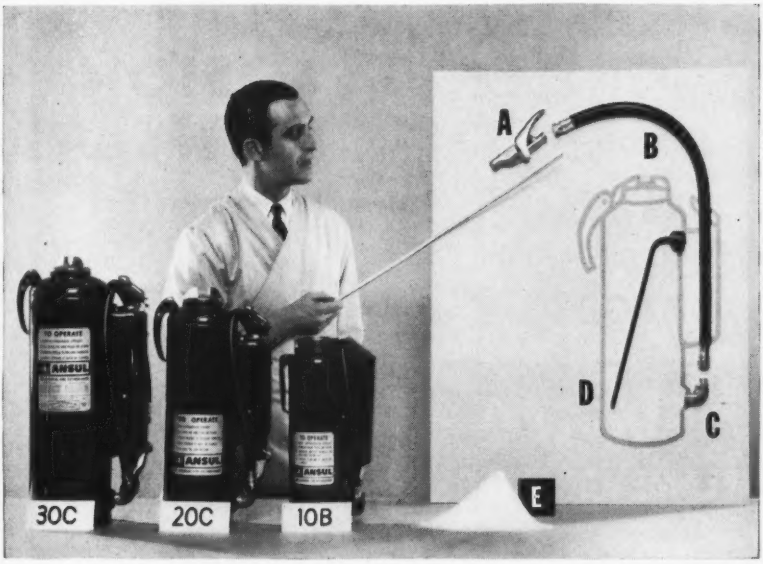
TOKHEIM CORPORATION

DESIGNERS AND BUILDERS OF SUPERIOR EQUIPMENT

1686 Wabash Avenue *SINCE 1901* **Fort Wayne 1, Indiana**

Factory Branch: 1309 Howard St., San Francisco 3, California

Canadian Distributor: H. Reeder, 205 Yonge Street, Toronto



A Nozzle redesigned for more uniform fire coverage, faster fire put-outs. **B** Hose with larger diameter gets more dry chemical to fire faster. **C** Elbow enlarged to accelerate flow of dry chemical. **D** Gas tube redesigned for more uniform gas pressure distribution. **E** PLUS-FIFTY B dry chemical gives improved performance over a wider temperature range.

Important design improvements in these Ansul Extinguishers give you more fire fighting power at no increase in price. Three years of research and more than 2000 fire tests turned up some significant new information on dry chemical extinguishment. Ansul engineers were able to design these findings into three new extinguisher models, the 10B, 20C and 30C. Result, greatly increased fire fighting power. All Ansul equipment is backed by a five-year warranty. This is the best way we know to say Ansul fire extinguishers are the finest of their kind made anywhere.

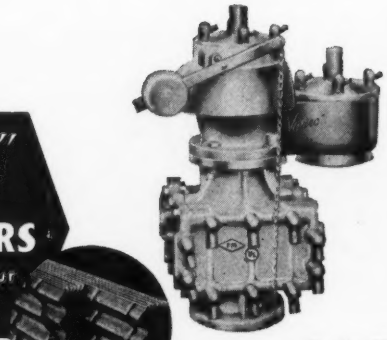
The Ansul Chemical Co., Marinette, Wisconsin

ANSUL

LOW COST
FIRE & EXPLOSION PROTECTION

for FLAMMABLE LIQUID STORAGE

WITH "Varec" FLAME ARRESTERS in combination with your VENT VALVES



Flame Arrester Unit listed by UNDERWRITERS' LABORATORIES Approved by Associated Factory Mutuals Laboratories and other governing agencies.

Fig. No. 5800A Conservation Vent Unit consisting of VAREC Vent VALVE in combination with VAREC FLAME ARRESTER

You can rely on VAREC CONSERVATION VENT UNITS to provide full fire protection on your liquid storage at low cost. Protection against entry of flame through the venting device is certain when Varec Flame Arresters are used. Protection against excessive pressure or vacuum is assured by the VAREC VENT VALVE. The combination unit gives you complete security against major hazards of flammable liquid storage. Average installation costs 1/10th of 1% of your investment in tank and products. Secure full details from your VAREC Representative or write factory.

NF-3

"Varec"

THE VAPOR RECOVERY SYSTEMS COMPANY

COMPTON, CALIFORNIA, U. S. A.

Cable Address: VAREC COMPTON USA (All Codes)

"Worthy of Your Confidence!"

Reliable Automatic Sprinkler Devices have been protecting life and property for more than 35 years. The practical design and rugged construction are universally approved and accepted by all Fire Insurance and Governmental Authorities. Reliable Automatic Sprinklers effect maximum reductions in fire insurance premiums.

Reliable's complete line provides a wide selection of Sprinkler Devices to meet any condition, including: Automatic and Open Sprinklers, Alarm Valves, Dry Pipe Valves, Accelerators, Electric Alarm Switches, Water Motors, and all Sprinkler System Accessories.

Experienced Reliable Licensees are located throughout the United States, Canada, and foreign countries. They are expertly qualified to design and install a Reliable Sprinkler System for your specific needs.

Manufactured and Distributed by

THE R ELIABLE AUTOMATIC SPRINKLER CO. INC.

MH

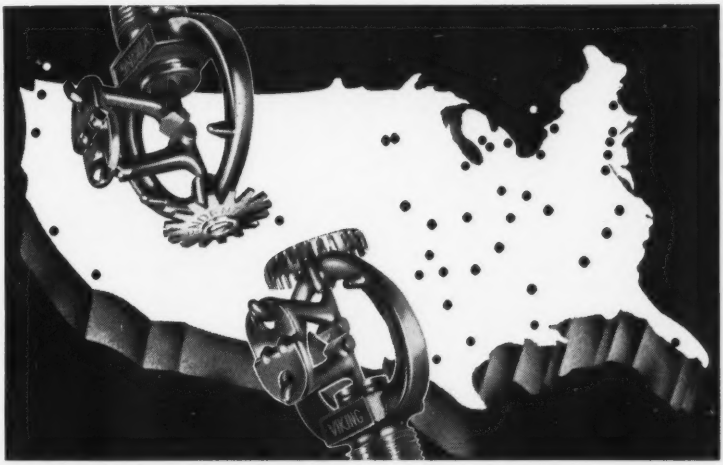
MOTOR OPERATED GATE VALVES

Electric motor operation is recommended for large M & H Gate Valves, or where valves are frequently operated, or where valves are located in remote, inaccessible or hazardous places. The remote control, possible with electric motor operated M & H Valves, is a convenience which frequently increases efficiency and reduces operating costs.

The 36" motor operated M & H Valve illustrated here is standard M & H Gate Valve design and construction—iron body, bronze mounted, double disc, parallel seat. All sizes of electric motor operated M & H Gate Valves are available in Class A for 50 lbs. working pressure, Class B for 100 lbs. working pressure or A.W.W.A. Class C for 150 lbs. working pressure. Furnished with hub, flanged or mechanical joint ends.

M&H VALVE
AND FITTINGS COMPANY
ANNISTON, ALABAMA

SUBSIDIARY OF W WALWORTH



VIKING SPRINKLER FIRE PROTECTION

for any condition whatever it happens to be!

ATLANTA — Crawford & Slaten Co. **BOSTON** — Viking Automatic Sprinkler Co. **BUFFALO** — Viking Automatic Sprinklers, Inc. **CHICAGO, MILWAUKEE** — Viking Automatic Sprinkler Co. **CINCINNATI, CLEVELAND, INDIANAPOLIS, LOUISVILLE** — Viking Sprinkler Co. **DALLAS, HOUSTON, JACKSON (Miss.), MEMPHIS, NEW ORLEANS, N. LITTLE ROCK, OKLAHOMA CITY, SAN ANTONIO, LUBBOCK, FT. SMITH, TULSA** — Texas Automatic Sprinkler Co. **DETROIT** — Viking Sprinkler Co. **GRAND RAPIDS** — Viking Sprinkler Co. of Western Mich. **HIGH POINT, N. C.** — Viking Sprinkler Co. **HUNTINGTON, W. VA.** — C. W. Hutchinson, Inc. **DECATUR (Ill.), DENVER, KANSAS CITY (Kan.), OMAHA, SAINT LOUIS, WICHITA** — Walton Viking Co. **LOS ANGELES, SAN FRANCISCO, PHOENIX** — California Viking Sprinkler Co. **HILLSIDE (N. J.), NEW YORK, MANCHESTER (Conn.)** — Viking Sprinkler Co. **PHILADELPHIA, WASHINGTON (D. C.), PITTSBURGH** — Viking Sprinkler Co. **PORTLAND (Ore.), SEATTLE, VANCOUVER (B. C.)** — Viking Automatic Sprinkler Co. **ST. PAUL, MINNEAPOLIS** — Hudson Viking Sprinkler Co. **TAMPA** — Florida Fire Sprinklers, Inc. **TORONTO (Ont.), WINNIPEG (Man.),** — Viking Automatic Sprinklers, (Canada) Ltd. **HASTINGS, (Mich.)** — The Viking Corporation.

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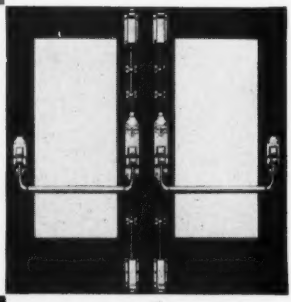
Get your exits

ready for increased traffic

Call in your



Von Duprin
"EXIT SPECIALIST"

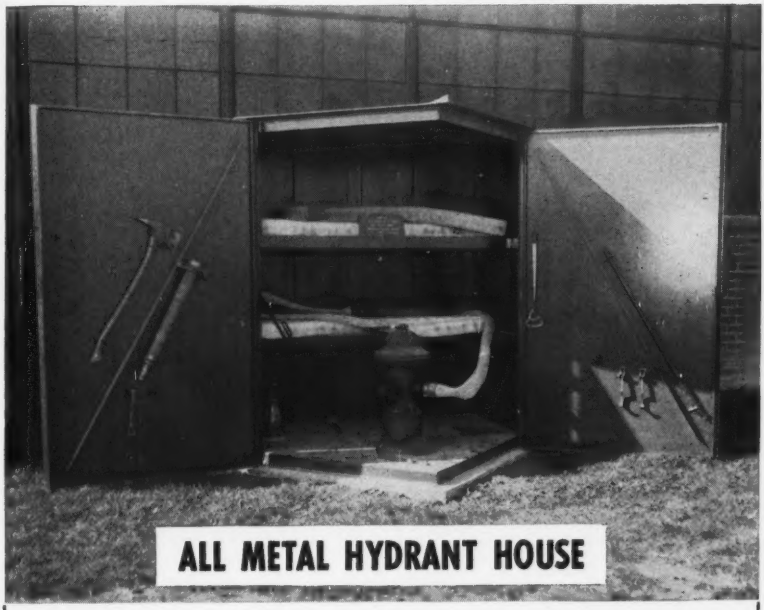
● Increased production for your plant means more employes, more traffic, more need than ever for safe, dependable exits. Call in your Von Duprin "Exit Specialist" for a free survey of your exit requirements. From actual experience, he can recommend the right Von Duprin exit devices to give you the greatest safety and service. Von Duprin is the most complete line of approved exit devices. From this one line, you can meet *all* your present and potential exit hardware needs. If you don't know the name of your nearest "Exit Specialist," write Von Duprin.

FREE Reserve a showing of Von Duprin's 20-minute sound movie, "Safe Exit." Build a lively safety program around this interesting public service film. Write for a booking.

VONNEGUT HARDWARE CO. • VON DUPRIN DIVISION • INDIANAPOLIS

Von Duprin Fire and Panic **EXIT DEVICES**

THE SAFE WAY OUT!



ALL METAL HYDRANT HOUSE

Many Architects and Engineers are specifying the Model 60 ALL-STEEL Hydrant House on new jobs and recommend their use for replacement of existing wooden houses as they wear out.

The advantage of a Hydrant House is that it protects the hose and hydrant during inclement weather when sleet or snow cause heavy icing. The hose is coupled and ready at any hour of the day or night. All steel houses are weathertight and rat proof — will not warp or dry out. (8) Eight Louvers are stamped in side panels for ventilation.

Doors are formed of 16 gauge metal. Roofs and side panels are 20 gauge. Shelves are perforated and formed of 14 gauge. Corner supports and hinge posts are formed of 12 gauge. Finished weight — 610 lbs.

Houses are shipped from stock, knocked down. Roof, base, shelves, doors and panels are completely prefabricated of galvanized iron with zinc plated hardware. Hinges are brass pinned. Two men with only a screwdriver and a wrench can erect it on foundations in less than one hour.

WRITE FOR QUOTATION ON YOUR REQUIREMENTS - NEW LOW PRICE

Manufactured by

VAN LOON INDUSTRIES

ENGINEERS AND FABRICATORS

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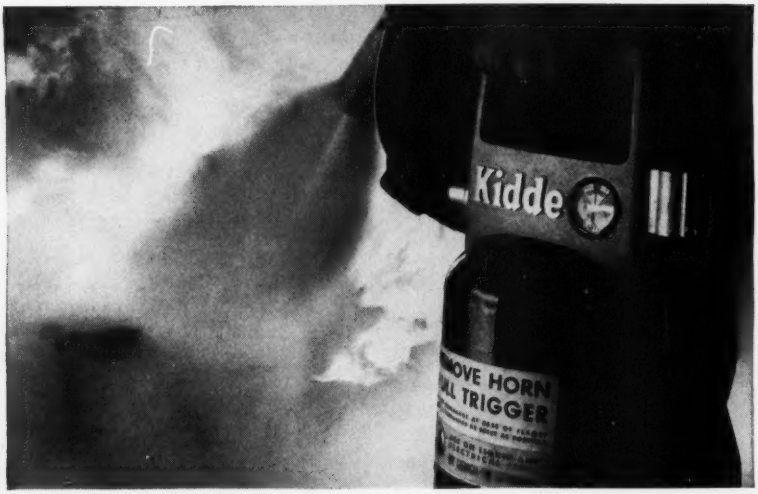
TWinbrook 3-4460 TWinbrook 3-4461



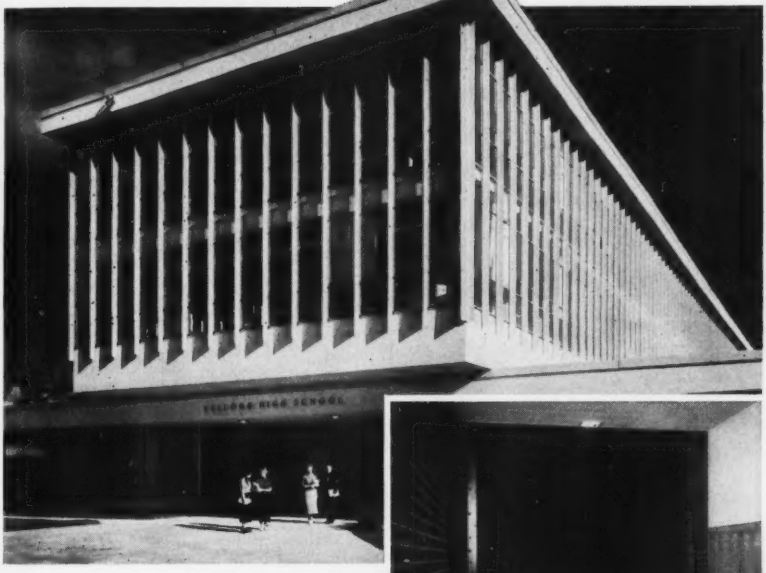
KIDDE'S NEW DRY CHEMICAL EXTINGUISHER ...FASTEST WAY TO KILL FIRE

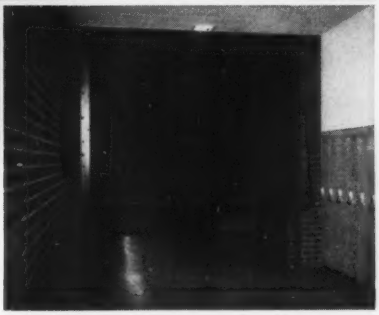
Here from Kidde is the newest, the fastest, the easiest-to-operate pressurized dry chemical fire extinguisher. Exciting new features include: extra-large aluminum handle (operate with gloves on); center-balanced (easier to carry); recessed pressure gauge (tells if unit is charged, ready for use); simplified directions . . . "Remove Horn" (trigger safety lock releases), "Pull Trigger" (instantly dry chemical kills fire). Comes in 20 and 30-lb. capacities. UL-approved. Requires only 225-250 psi charging pressure. Write Kidde today for name of nearest distributor.

Kidde (K Kidde)

Walter Kidde & Company, Inc.
1051 Main Street, Belleville 9, N. J.
Walter Kidde & Company of Canada Ltd., Montreal—Toronto

MODERN FIRE PROTECTION





Kinnear Rolling Fire Doors

This striking new high school at Kellogg, Idaho, presents architectural progress at its best. Right at home in this modern setting are six Kinnear Rolling Fire Doors, like the one at right — with the interlocking steel-slat curtain originated *by Kinnear* nearly 60 years ago. Like the school itself, these doors owe much of their eye appeal to basic, functional efficiency. In case of fire, they lower *automatically*, blocking the spread of flames. Positive, spring action starts them, yet downward speed is *controlled* for safety. And they can be opened after automatic closure, if necessary. For extra fire protection plus highest safety for building occupants install Kinnear "AKBAR" Rolling Fire Doors (labeled by Underwriters Laboratories, Inc.)

For all regular (non-fire) needs, standard Kinnear Rolling Doors save space, time, and cut costs. They give added protection against fire, wind, weather, trespass, and vandalism. Built any size; motor or manual control.

Write Today For Full Details

The KINNEAR Manufacturing Co.

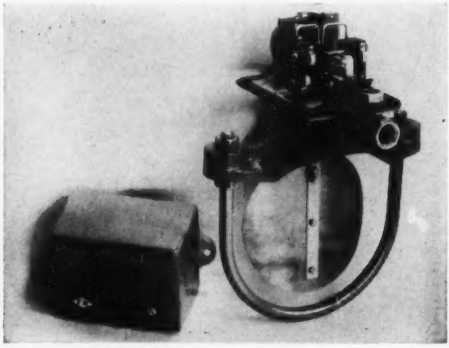
Factories: 2250-70 Fields Ave., Columbus 16, Ohio
1742 Yosemite Ave., San Francisco 24, Calif.
Offices and Agents in All Principal Cities

KINNEAR
ROLLING DOORS
Saving Ways in Doorways

CENTRAL STATION SIGNALS, INC.

Manufacturers of all kinds of approved devices used in Central Station Systems or Class 'A' or Class 'B' Proprietary Fire Alarm Systems, either automatic or manual.

53 WEST 23rd STREET . . . . . NEW YORK 10, N. Y.



Model PRS-1

Sprinkler

Waterflow Alarm

This device is approved by Factory Mutual Laboratories and Underwriters' Laboratories, Inc.

- This device is also made as Model PRT-1, a coded waterflow transmitter.

5-inch size shown above. To install simply drill 2-inch hole in pipe.

- Also made in explosion proof models.
- Made in all sizes from 2½" to 8".
- Has instantly recycling pneumatic retarding device, which prevents false alarms.
- Has enclosed electrical contacts for any voltage not exceeding 15 amp. 125 volts, A.C. and ½ amp. 125 volts, D.C. Operates on all water pressures or surges.

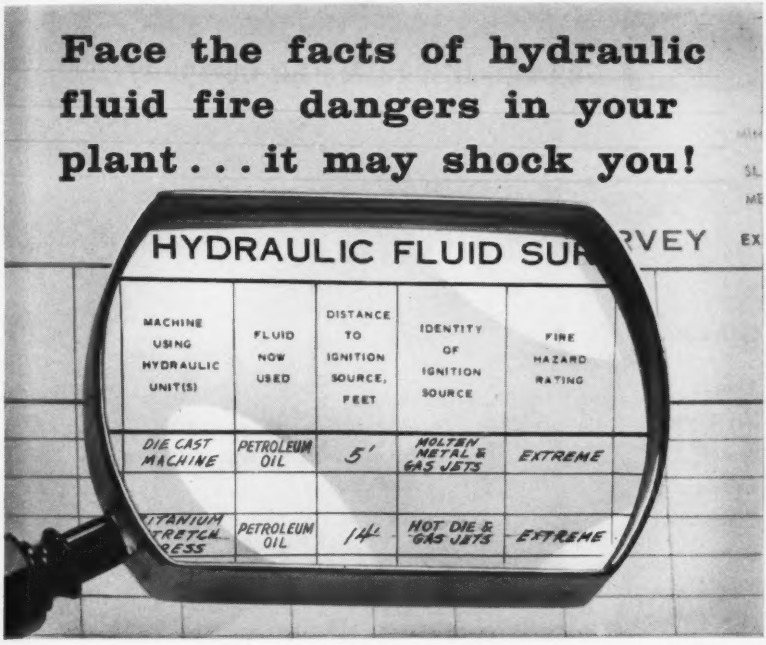
Tempo-Set Model A Fire Detector

Underwriters' Laboratories, Inc. Approved.

- Self restoring and can be heat tested.
- Electrical contacts are silver or gold and are enclosed.
- Very reasonable price.

Size is 1⅝" x ⅝"

- Tempo-set Model A is approved in either open or closed circuit and the temperature ratings are 135 and 200 degrees.
- Approved spacing is 20' x 20'.
- Electric ratings are 125 volts 1 ampere, A.C. or 24 volts 0.5 ampere D.C. or less.



Write today for your free HYDRAULIC FLUID SURVEY SHEET

Monsanto's Hydraulic Fluid Survey sheet enables you to make an appraisal of the risk you take by using flammable hydraulic fluid in a machine near a source of heat. If you're shocked at the way you've been flirting with the possibility of a fire, switching to fire-resistant Pydraul F-9 hydraulic fluid will ease your mind. Send for your Survey sheet—today. It and Pydraul may save you from a staggering fire loss.

Pydraul: Reg. U. S. Pat. Off.

Pydraul F-9 is the first and only fire-resistant hydraulic fluid to be listed by Underwriters' Laboratories.

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WHERE CREATIVE CHEMISTRY WORKS WONDERS FOR YOU

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MONSANTO CHEMICAL COMPANY
800 N. 12th Blvd., St. Louis 1, Missouri

Please send me ( ) free copies of the Hydraulic Fluid Survey sheet.

(Your name).....

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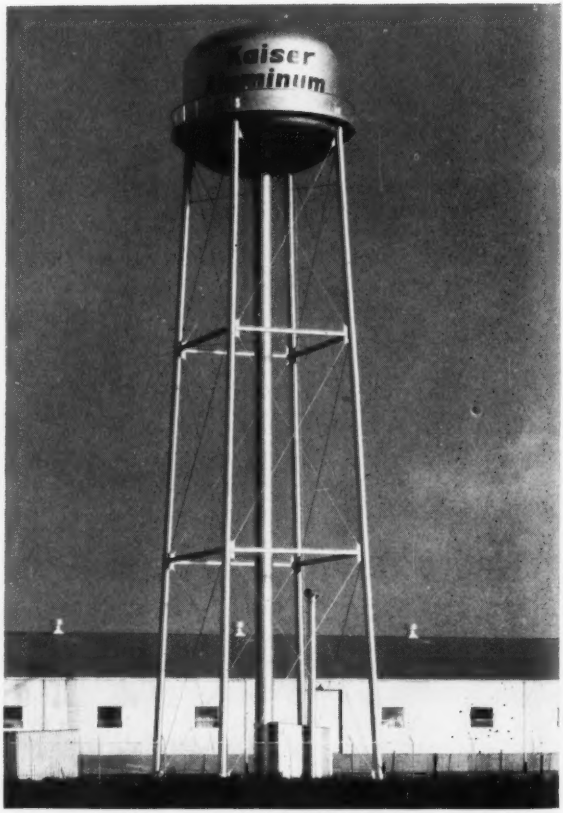
Chicago Bridge & Iron Company



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IN CANADA:
Horton Steel Works Limited

Horton Tank Provides Dual Service and Aids In Insurance Savings

The new food container plant of Kaiser Aluminum and Chemical Corporation, near Wanatah, Indiana, has 50,000 gallons of water for fire protection and 25,000 gallons for general plant use stored in a 75,000 gallon ellipsoidal bottom elevated tank with a height to the bottom capacity line of 100 feet. Studies of insurance savings that would result from the sprinkler protection prompted the decision to erect this tank which is sufficiently large for future plant expansion.

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Specialized Help on Fire Alarm System Specifications

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CATALOG F249
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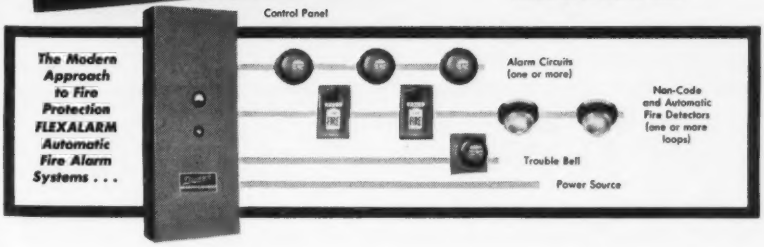
FIRE ALARM SYSTEMS
MANUAL AND AUTOMATIC FIRE ALARM SYSTEMS FOR SCHOOLS, HOSPITALS, INSTITUTIONS, PUBLIC BUILDINGS, HOTELS, MANUFACTURING AND MERCANTILE PROPERTIES

New Catalog for Architects and Engineers

Here's an advanced, easy-to-use technical digest on the design, application and specification of interior fire alarm systems. It features a new building-block concept based on Gamewell experience in signaling and communications. F249 includes suggested systems and layouts, gives you a complete one-source reference for planning the best possible protection against the hazards of fire.

GAMEWELL

THE GAMEWELL COMPANY
Newton Upper Falls 64, Mass.


The Modern Approach to Fire Protection FLEXALARM Automatic Fire Alarm Systems . . .
Control Panel
Alarm Circuits (one or more)
Non-Code and Automatic Fire Detectors (one or more loops)
Trouble Bell
Power Source

SEVERE TESTS* PROVE STARGARD SUPERIORITY

No sprinkler was ever subjected to more severe tests than the new "Stargard" Automatic Sprinkler.

* This is the fourth in a series of advertisements describing these tests conducted by the Underwriters' Laboratories, Inc.

☑ CORROSION
☑ PAINT LOADING
☑ ROUGH USAGE
☑ OVERALL STRENGTH

OVER-ALL STRENGTH TEST #4

Gradually increased loads were applied to the inner surface of the cap enclosure by a tensile strength testing machine to determine the strength of the releasing mechansim. The frame arms of three complete sprinklers so tested yielded at maximum loads of 1,034 lbs., 975 lbs. and 1,100 lbs.

These tests prove the ability of the strut assembly to withstand even greater stress than the sprinkler frame and indicate that the parts will not yield under the normal loads impressed on completed sprinklers.

It is important to note that the pyrex glass balls did not crack or chip at any time during the test operations.

LISTED BY UNDERWRITERS' LABORATORIES, Inc.

APPROVED BY FACTORY MUTUAL LABORATORIES

For further particulars, write today.

STAR SPRINKLER CORPORATION

Westmoreland and Collins Sts. — Philadelphia 34, Pa.

Licensees in all Principal Cities of the United States and Canada

NOW... Kuhns ductile iron fittings

For Sprinkler Systems

Kuhns ductile iron pipe fittings—the newest development in piping—provide an extra margin of operating safety for sprinklers, high pressure lines and other vital piping systems. High structural strength and resistance to thermal shock help these fittings prevent leakage caused by vibration, temperature changes or misalignment.

"K" Pipe Lock Couplings

Listed for 800 psi by Underwriters' Laboratories, Inc., these couplings have a safety factor of five times the UL listing for 2½" through 6" and four times UL listing for 8". Sizes: 2½" through 8". Look for the "800 D" on each.

"K" Flanges and Flanged Fittings

Pressure rating, 500 psi by Underwriters' Laboratories, Inc. for elbows, base elbows, 45° elbows, side outlet elbows, tees, side outlet tees, and reducers in straight and reducing sizes. Flat faced flanges standard. Extra heavy flange dimensions and raised faces available. Look for the "DI 500" on each.

Complete range of sizes through 12".

"K" Screwed Fittings *

Pressure ratings listed by Underwriters' Laboratories, Inc.

STEAM AND OIL AT 550°F

¼" to 3".....300 lbs.

LIQUID AND GAS AT 150°F

¼" to 1".....2000 lbs.

1¼" to 2".....1500 lbs.

2½" to 3".....1000 lbs.

*Ductile iron fittings are available in any size in Kuhns complete cast iron line, ¼" through 12".

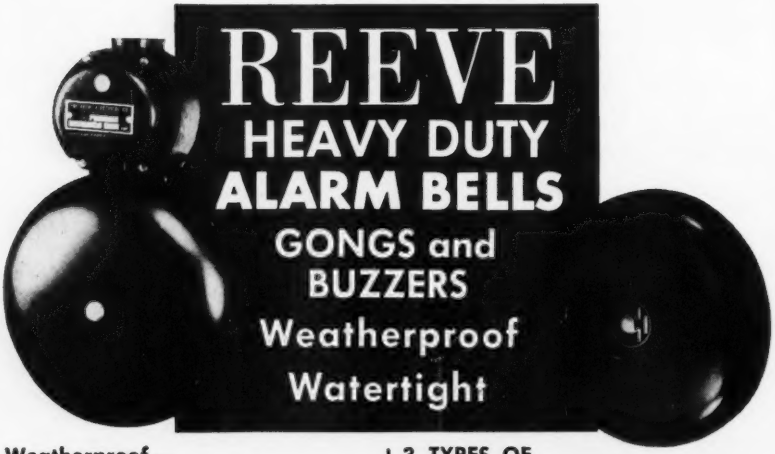
Note: These fittings are excellent for liquefied petroleum gas systems. Look for the "DI 300" on each.

Send for our catalog or contact your wholesaler.

THE KUHNS BROTHERS CO.

1800 McCALL STREET, DAYTON, OHIO

1887 • 70 Years of Continuous Progress • 1957



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HEAVY DUTY ALARM BELLS
GONGS and BUZZERS
Weatherproof
Watertight

Weatherproof —
Sizes 3", 4", 6", 8", 10", 12"
DC—6—220 V. · AC—12—220 V.

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OPEN PIGTAIL • WEATHERPROOF • E-Z MOUNT
Sizes 6", 8", 10". Cast aluminum housing
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Single Stroke and Vibrating Types
Voltages are the same as Neck Type

Special Windings on request.

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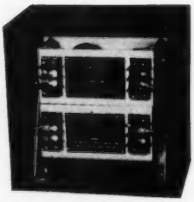
AUTOMATIC BATTERY CHARGER, High and Low Current

The unit is designed for use on any storage batteries not subject to heavy drains. It will trickle charge the battery indefinitely because of its automatically decreasing rate of charge.

For use with six cells (12 volts). Automatically controlled by saturable reactor. Continuous output one ampere. 22.5 watts, 118 volts, 60 cycles. 3% Regulation. 9" x 9" x 6" — 14 B & S gauge steel wall cabinet. 15¼ lbs. U.L. Approved. No moving parts.



MODEL BC-12

Manufacturers of a complete line of
CENTRAL OFFICE and LOCAL FIRE ALARM DEVICES
• automatic alarm devices • sprinkler alarm and supervisory devices • burglar alarm devices and accessories. DYNALARM (sound detection for both reverberant and non-reverberant vaults).

THE REEVE ELECTRICAL CO., Inc.
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IMPROVED "DETECTOR" CHECK VALVE

4", 6" and 8" SIZES
For POSITIVE POLICING of WATER WASTE in Plant Fire Service Connections
SAVES EXPENSE OF FULL SIZED FIRE SERVICE METER — COMBINES MAXIMUM EFFICIENCY WITH MINIMUM COST.

Manufactured and Installed by
GLOBE AUTOMATIC SPRINKLER COMPANY
2035 Washington Avenue — PHILADELPHIA 46, PA.

this was so unnecessary

A Blaw-Knox Automatic Sprinkler System could have prevented it

Most uncontrolled fires are unnecessary. The damage in property destroyed, plants lost, inventories wiped out, records ruined, and businesses shut down can never be recovered. A Blaw-Knox *Automatic* Sprinkler System can stop fires at their origin, minimize damage to a small area, and pay for itself in a few years by savings in reduced insurance premiums.

"Little Joey Sprinkler" always on the job.

BLAW-KNOX COMPANY

Automatic Sprinkler Department
Power Piping and Sprinkler Division
829 Beaver Avenue, Pittsburgh 33, Pa.

VICTAULIC

VICTAULIC COUPLINGS*

Styles 77, 77-D for standard applications. Simple, fast to install — sturdy and reliable. Sizes ¾" to 30". Style 75 Light-Weight Couplings for light-duty applications. Sizes 2" to 8". Additional styles for cast iron, plastic and other pipes. Sizes through 60".

ROUST-A-BOUT COUPLINGS *

Style 99 for plain or beveled end pipe. Best engineered, most useful plain end joint on the market. Simple, husky — easy and fast to install. Takes strong bull-dog grip on pipe. Sizes 2" to 12".

VICTAULIC FULL-FLOW FITTINGS

Complete line of Elbows, Tees, Reducers, Laterals, etc. — to fit all Victaulic Couplings. Streamlined for top efficiency, easy to install. Sizes ¾" to 12".

VIC-GROOVER TOOLS

Handy, on-the-job grooving tools that do the job in half the time. Light weight, easy to handle — operate manually or from any power drive. Automatic groove position and depth. Sizes ¾" to 8".

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Proven for 28 years on both wet and dry Fire Protection Systems. Standard with most major sprinkler companies for bulk-run and cut-in piping. Victaulic Couplings are installed in *less than one-half the time* required for other standard pipe joints.

THE EASIEST WAY TO MAKE ENDS MEET

VICTAULIC
COMPANY OF AMERICA
P.O. Box 509, Elizabeth, N. J.

Nation Wide
Central Station Protection Services

Sprinkler Valve Alarm — Complete Sprinkler Supervisory — Manual Fire Alarm — Automatic Fire Alarm — Temperature Alarm — Oil Burner Supervision — Burglar Alarm — Hold-Up Alarm — Vault & Safe Protection

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For
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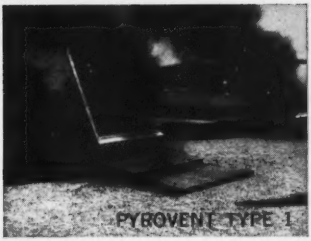
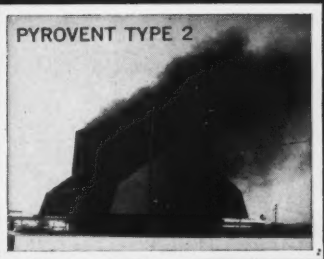


Include WASCOLITE PYRODOMES! Smoke, flames, explosive gases are vented automatically for complete protection. WASCOLITE PYRODOMES and PYROVENTS make sprinklers doubly effective in reducing dangerous temperature build-ups on roof decks. Your fire protection is assured with WASCOLITE PYRODOMES and PYROVENTS!



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WASCO PRODUCTS, INC.

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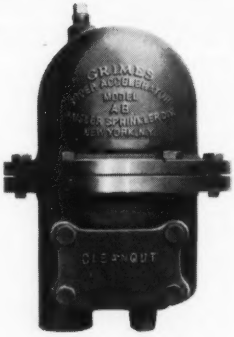
NEW IMPROVED GRIMES MODEL AB SUPER ACCELERATOR

SPEEDS UP DRY PIPE VALVE OPERATION



ALL BRONZE

EASY TO INSTALL

SIMPLE TO SERVICE

GRIMES DEVICES ARE ENGINEERED FOR BETTER PROTECTION . . . .

THERE IS A GRIMES LICENSED REPRESENTATIVE NEAR YOU WHO IS EQUIPPED TO DESIGN AND INSTALL A FIRE SPRINKLER SYSTEM TO MEET YOUR SPECIFIC NEEDS.

GRIMES DEVICES ARE APPROVED BY ALL INSURANCE INTERESTS

Manufactured and Distributed by

RAISLER SPRINKLER DIVISION

RAISLER CORPORATION, 129 Amsterdam Ave., New York 23

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FLAMMABLES OPERATIONS GUIDES

for Prevention of Fires from Unloading and Transferring through to Washing, Cleaning, Swabbing and Disposal

Equipment Selection Guide—a compact, concise illustrated chart containing a selection of various plant operations and the equipment suggested for fire prevention.
Easy to use—Standard 8½″ x 11″ note book size—Laboratory Approvals indicated.

Catalog of Equipment for Safe Storage, Handling and Use of Flammables—with supplementary sheets illustrating 27 different types of safety and operating containers with sketches showing applications and construction features. Contains a special description and illustration of the Protectoseal perforated metal double-wall fire baffle.

Drum Storage and Dispensing Catalog—gives complete explanation of the hazards and problems in delivery, storage and dispensing; describes and illustrates the various protective devices available and explains their application and use. Contains detailed specifications and gasket recommendations for various flammables.

Venting Fundamentals with Protectoseal Equipment—a new presentation from a functional viewpoint of vapor conservation venting, filling operations, tank car and tank truck loading and unloading, refueling operations—complete with specification data and venting air-flow charts.

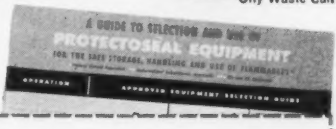
Protectoseal provides the ONE complete source of APPROVED Fire Preventive Equipment for ALL Flammables Operations with over 100 specialized containers and devices for protection in every department and every activity all through the plant.

Engineering and Design Service—With the increased use of flammable solvents in production processes, there are undoubtedly some applications for which no special equipment is presently available. In such cases, consult with our sales engineers or contact factory direct. Our engineers and designers are interested in knowing of new applications and we are frequently able to produce new types of safety equipment which fit easily into the process.

PROTECTOSEAL PRODUCTS
PROTECT YOUR PLANT

Fill in coupon and attach to company letterhead.

West Coast Warehouse —Los Angeles, Calif. In Canada— Safety Supply Co. Toronto.



THE PROTECTOSEAL COMPANY
1968 So. Western Avenue, Chicago 8, Illinois

Send "A Guide to Selection and Use of Protectoseal Equipment for Safe Storage, Handling and Use of Flammables." Also send the complete catalogs checked below:

☐ Safety Can Catalog ☐ Drum Storage Catalog ☐ Vent and Fitting Catalog containing Venting Fundamentals

Name_____ Title_____

Company_____

Address_____

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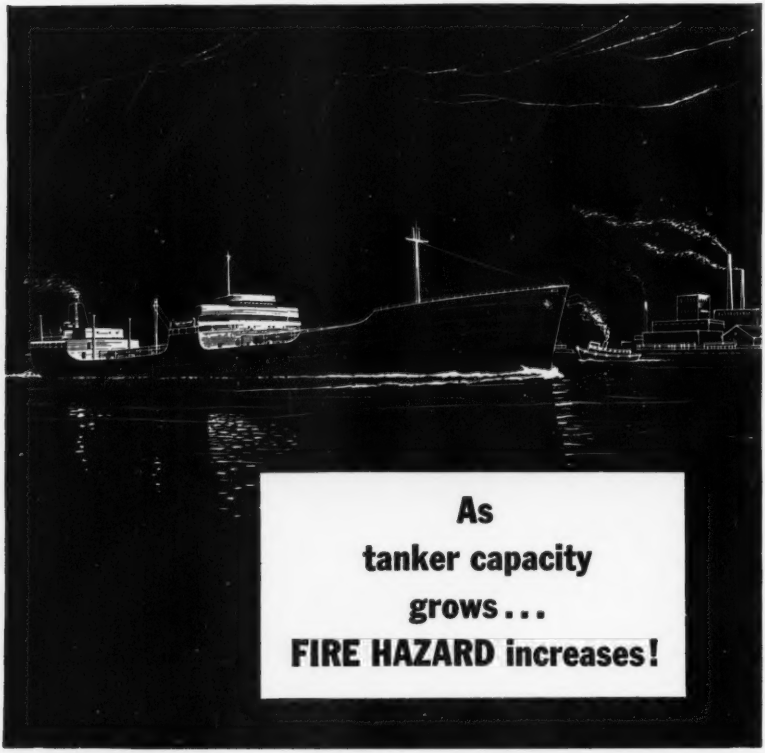


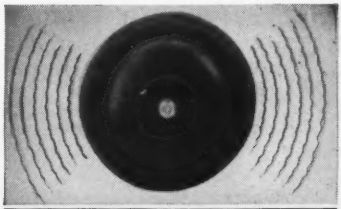
New, larger tankers now help meet the nation's needs for a greater flow of liquid fuels. But as tonnage grows, so does fire hazard . . . both in the ships themselves and in the docks that serve them. If the big new tankers have a place in your business, be sure your fire protection program is adequate.
For specific suggestions, call National Foam.

NATIONAL FOAM System, Inc.
West Chester, Pa.

NATIONAL FOAM FIRE PROTECTION SYSTEM

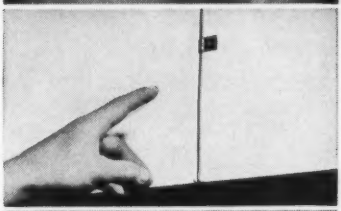
The only company exclusively engaged in the design, development and manufacture of foam fire protection equipment and chemicals.

FIRE ALARM!



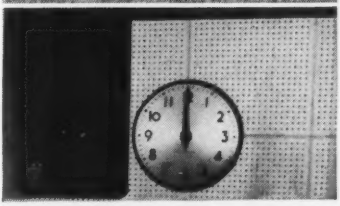
AT THE FIRST HOT BREATH OF FIRE

KIDDE'S ATMO ALARM SYSTEM
(using rate-of-temperature-rise tubing)



TRIGGERS ALARM AT FIRE AREA
(outside building or at local fire department)

GIVES FIRE LOCATION AT ANNUNCIATOR PANEL
(usually at manned telephone switchboard)

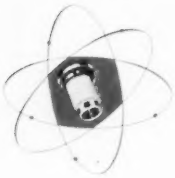


Save priceless lives, save valuable buildings with Kidde's Atmo Fire Alarm System. This wide-area automatic fire detecting and warning system sounds alarm almost the moment fire starts. Ideal where life protection and early fire warning is essential, the Kidde-Atmo system operates independently of regular power sources, gives protection even if outside power fails. What's more, the system can close doors, shut off fans, motors, blowers. Is automatically self-resetting after use or test. Write today for Kidde's Atmo Alarm System booklet.

Kidde—Atmo
FIRE DETECTION
J. H. SCHARFF, INC.
1051 Main Street, Orange, N. J.
A Subsidiary of
Walter Kidde & Company, Inc.

Nuclear energy takes over the fire watch...

"Give us those
FIVE PRECIOUS MINUTES!"



In a few brief minutes a microscopic spark can be the beginning of a dangerous, destructive fire. Nuclear energy, adapted to an electronic device, has now found a way to save those vital minutes. PYR-A-LARM, the nuclear-energized pre-detection system, acts faster because it reacts to the invisible products of combustion. It signals the alarm long before conventional thermal devices can function.

If you would like a demonstration of the advantages of PYR-A-LARM protection in your plant, or additional information, write today. *Approved by Underwriter's Laboratories Inc. and Factory Mutual Laboratories.*

these are some of the firms that have installed **PYR-A-LARM**

Pyrotronics
A DIVISION OF BAKER INDUSTRIES, INC.

North American Aviation, Inc.
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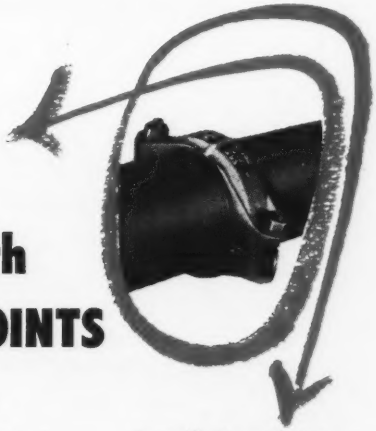
NUCLEAR FIRE DETECTION AND ALARM SYSTEMS

P. O. Box 390, Newark 1, New Jersey

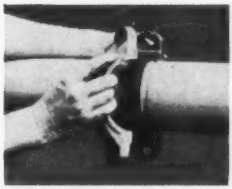
Couple Pipe the Easy, Low Cost Way with New G-B GRUVAJOINTS



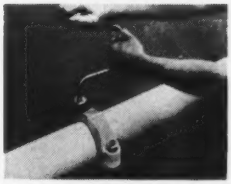
Now you can save up to 25% when connecting pipe for bulk runs and risers. Yes, contractors are saving money every day when they use new lightweight Gruvajoints. There's no flanging, no threading, no welding, and there's no need for heavy chain tongs or pipe wrenches. Gruvajoints are truly the modern way to couple pipe. Write today for free illustrated brochure on G-B Pipe Coupling Products. Gruvajoints are now available in 2", 2½", 3", 4", 5", 6" and 8" sizes.

Install Gruvajoints in three easy steps

Grease gasket and center over pipe ends.



Lay housing halves into grooves and insert bolts.



Tighten the two nuts equally.

LISTED by
Underwriters' Laboratories, Inc.
File EX 1741A and B

APPROVED by
Factory Mutual Engineering Division
Report Serial No. 13097

GUSTIN-BACON
manufacturing company
210 W. 10th St. Kansas City, Missouri

Technical Men seeking a challenge . . . ever think of MARKETING as an opportunity?

Step into new Fields with NOTIFIER

leading manufacturer of U.L. & F.M. listed automatic fire detection systems, sprinkler supervisory equipment, and municipal fire alarms.

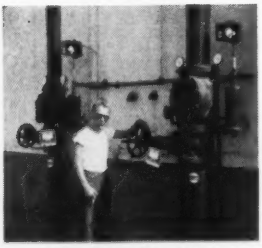
Demonstrating newest proprietary system to interested fire officials

A limited number of district **sales areas** are available to outstanding men of vision, organizing ability and technical competence who can build an alert, aggressive dealer organization. As a progressive manufacturer of quality alarm signaling equipment, NOTIFIER is anxious to complete its nationwide sales distribution.

Preparing to visit plant engineers

Or . . . attractive **dealer franchises** can be secured by men of character and integrity possessing a good sales and service record, or equal achievements, who would be happy operating a successful, independent fire alarm business.

The men selected are provided training in — local and national fire regulations, application of sound fire prevention and protection principles, marketing analysis, installation and servicing of **NOTIFIER** fire alarm equipment in industrial, institutional or municipal applications.



Inspecting and servicing a NOTIFIER system

Write for full details and send resume of experience to:

NOTIFIER FIRE ALARM

Field Sales Manager
NOTIFIER CORPORATION
Dept. K
239 South 11th Street
Lincoln 8, Nebraska

Recall the old saying "An ounce of prevention is worth a pound of cure". Lexsuco Fire-Retardant Roof Constructions can be the "ounce of prevention" for your building. A Lexsuco Roof eliminates flammable asphaltic materials from between the roof deck and insulation. It will not feed a fire, will not spread a fire and eliminates dense, black smoke, making fire-fighting possible. Make the building you build or insure fire-retardant with Lexsuco Roof Constructions.

. . . fire-retardant roof constructions

APPROVED BY FACTORY MUTUAL AND FACTORY INSURANCE ASSOCIATION

LEXSUCO, INC.
Department FA-77
4815 Lexington Ave.
CLEVELAND 3, OHIO

WRITE FOR INFORMATIVE BROCHURE

Name & Title_____
Firm_____
Address_____
City_____ Zone____ State_____

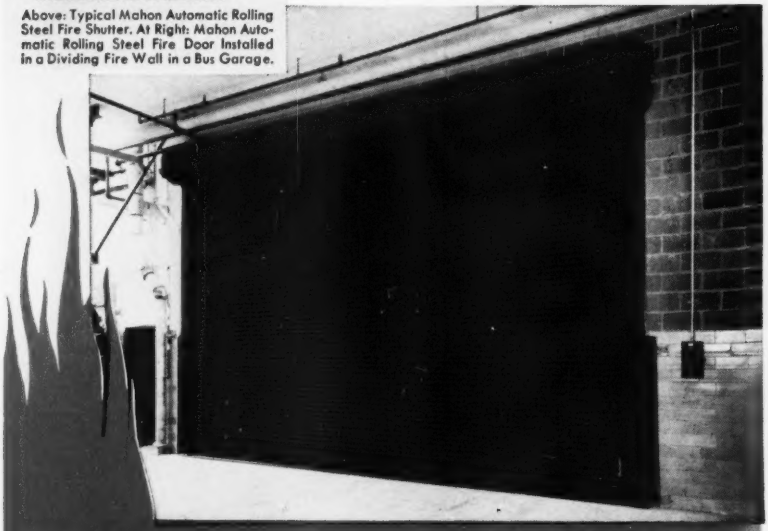
LEXSUCO
INCORPORATED
4815 LEXINGTON AVENUE
CLEVELAND 3, OHIO
TELEPHONE EXpress 1-3838

Automatic Rolling Steel
FIRE DOORS *and* WINDOW SHUTTERS
PREVENT SPREAD *of* FIRE!

You need good automatic fire doors in fire walls, corridors, and vertical shafts . . . in some cases automatic rolling steel window shutters are necessary to protect your building and its contents from fires which may originate in nearby buildings. Many, many cases are on file which confirm that timely action of automatic rolling steel fire doors and window shutters have confined a fire to its point of origin and permitted its being extinguished with comparatively small damage. Make a survey of your building now, and don't delay action. You will find a Mahon Automatic Rolling Steel Fire Door or Window Shutter to meet each of your requirements—all bear the Underwriters' Label. These automatic fire doors may be operated manually or mechanically in every day use. If a fire should break out while they are in the open position, the automatic mechanism will close the door, cutting off drafts and preventing the spread of the fire. See Sweet's Files for complete information, or write for Catalog G-57.

THE R. C. MAHON COMPANY • Detroit 34, Michigan
Branch Offices in New York and Chicago • Representatives in Principal Cities
Manufacturers of Standard and Underwriters' Labeled Automatic Rolling Steel Fire Doors and Window Shutters; Underwriters' Rated Metalclad Fire Walls; Insulated Metal Curtain Walls; Electrified M-Floors; Steel Roof Deck; Acoustical Long Span M-Decks; and Acoustical and Troffer Forms.

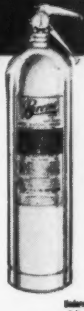
Above: Typical Mahon Automatic Rolling Steel Fire Shutter. At Right: Mahon Automatic Rolling Steel Fire Door Installed in a Dividing Fire Wall in a Bus Garage.



MAHON ROLLING STEEL FIRE DOORS and WINDOW SHUTTERS

A single match could close your doors for good!

A carelessly discarded match can hang a "Closed" sign on your business — *in a matter of minutes!* Any fire can get out of control — fast — unless barricaded and stopped by a Pyrene C-O-Two *safety-engineered* extinguisher. Call your local Pyrene-C-O-Two distributor today! He carries a complete line of quality extinguishers, systems, brass goods, hose and accessories. Or write to:



Underwriters' Laboratories and Factory Mutual Approved

Pyrene C-O-TWO

PYRENE-C-O-TWO DIVISION

THE FYR-FYTER COMPANY
Dept. NFPA Newark 1, New Jersey

BRANCHES IN ATLANTA • CHICAGO • DALLAS • DETROIT • SAN FRANCISCO

He's leaving an important message for you!

When a gas-vent installer places the red-and-black Metalbestos "Safety System" Seal above a gas appliance's draft hood, he's giving the finishing touch to a safe, trouble-free gas vent. It's his assurance to inspectors that an all-Metalbestos gas vent has been designed and installed according to the Metalbestos "Safety System" Gas Vent Tables.

Watch for the Metalbestos "Safety System" Seal. It's the quality symbol of a modern gas vent . . . scientifically guaranteed for safe performance and life-time service.

METALBESTOS DIVISION
WILLIAM WALLACE COMPANY · BELMONT, CALIF.

Stocked by principal jobbers in major cities. Factory warehouse in Akron, Atlanta, Dallas, Newark, Des Moines, Chicago, New Orleans, Los Angeles.

For your complimentary copy of the new "Safety System" Installation Guide, contact your nearest Metalbestos representative or write Dept. T-10

safety is paramount

– in every country

– in every currency

– in every language

SAFETY has about the same connotation throughout the Petroleum Industry of the World—whether it be in the steaming jungles of Indonesia, the burning sands of the Middle East, or on the endless plains of TEXAS.

Life is dear to every man, whether he be a laborer or a man of high estate. His SAFETY is of deep concern, not only to himself, but to those dependent upon him—his family and his employer.

Petroleum equipment like petroleum itself is very valuable, and the more inaccessible and distant its location, the higher its cost becomes. Wherever it is, it is worth PROTECTING and the entire Petroleum Industry is alert to providing the necessary safeguards.

For nearly Forty Years, SHAND & JURS COMPANY has been a leading supplier of SAFETY and CONSERVATION EQUIPMENT to the Petroleum Industry of the World, and to make it available to all who need it, identical equipment is made both in the United States and in Great Britain, so if you deal in Dollars or in Pounds you may avail yourself of the Worlds Best in TANK SAFETY, CONSERVATION and ACCESSORY EQUIPMENT.

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MONTREAL Lytle Engineering Specialties, Ltd., 360 Notre Dame St. W.
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VANCOUVER P. D. McLaren & Son, Ltd., 3277 Main Street
CALGARY P. D. McLaren & Son, Ltd., 510 – 9th Ave. W.
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CARACAS Lyndon Soanes, C.A., Edificio Galipan
ENGLAND Whessoe, Ltd., Sales, 25 Victoria St., London S. W. 1
Whessoe, Ltd., Works, Darlington, County Durham

New Design Sprays Water More Evenly Over Wider Area!

It's hard to improve on the best, but we've done it! By re-designing our already superior "Automatic" Spray Sprinkler, we have come up with a model that has an even *better* distribution pattern. We also made the casting more rugged. The resultant increase in efficiency means better performance in case of fire. While we were at it, we improved our sprinkler's appearance.

Available for upright or pendant installation.

Ask your nearest "Automatic" Sprinkler fire safety engineer or write to us for complete information.

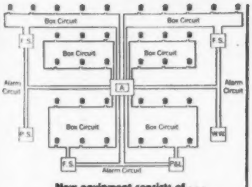
"AUTOMATIC" SPRINKLER CORPORATION OF AMERICA
YOUNGSTOWN, OHIO
OFFICES IN PRINCIPAL CITIES OF NORTH AND SOUTH AMERICA

"Automatic" Sprinkler

FIRST IN FIRE PROTECTION

Lancaster, Pa., Reports...

New Automatic Alarm System Speeds Response to Alarms — Gives Extra Protection to Citizens



New equipment consists of . . .

Type B, Form 4 Central Office, replaces one installed in 1896.

Voice Communication Equipment between central office and outside Fire Stations.

FIRE FACTS

Gamewell Type B Fire Alarm System is completely automatic. Box circuits go to Central Alarm Station from where Alarm Circuits connect Fire Stations and all important Emergency Centers. Recording devices, and audio and visual alarm signals are furnished as required.

Remember-a Gamewell System is FIRST when seconds count!

A new Gamewell Type B, Form 4 Automatic Coded Telegraph Fire Alarm System is now on the job in Lancaster, Pa. It gives Chief Harry Miller a big edge in protecting life and property against the hazards of fire in his community.

Here's how...

At the instant a fire box is "pulled", coded signals are automatically transmitted to Fire Headquarters, and immediately retransmitted to all engine houses, the water department, police department, power and light plant and the fire chief's home — all simultaneously.

Result...

The entire fire defenses of Lancaster are mobilized within seconds . . . automatically. Men and equipment get to the scene during the vital first seconds of the emergency. The citizens are assured of the most effective fire fighting possible.

Ask for ALL the Facts

Gamewell experience with all types of fire alarm and signalling systems can help your community plan for maximum fire defense. A special FACTS KIT is available to answer questions on fire alarm systems and Gamewell will be happy to conduct a FREE Survey to assist you in planning. Write or call . . .

THE GAMEWELL COMPANY
Newton Upper Falls 64 Massachusetts
In Canada: Northern Electric Co., Ltd., Belleville, Ont.

GAMEWELL®

THE BOX IS POSITIVE · REDUCES HUMAN ERROR

For Blanketing Fire in Gasoline, Oils and many Chemicals

These pictures were taken at Robins Air Force Base in Georgia during tests of a Grinnell ProtectoFoam System. Above, a man slogs through foam to check the spray pattern produced by over 800 nozzles discharging 75,000 gallons of foam per minute.

With a ProtectoFoam system, a vapor tight blanket of foam floats on liquids and clings to solids, extinguishing flames and preventing re-ignition. It is effective against fires in gasoline, oils and many chemicals.

The foam, a harmless mixture of water and a protein base foaming agent, is produced mechanically by special Grinnell nozzles. When the compound has been used up or shut off, these nozzles then discharge water similar to standard open sprinklers. Once the fire is out, the water discharge may be used to wash down the building and equipment and clean away the foam.

ProtectoFoam is only one of many Grinnell Fire Protection Systems designed for special hazard application. For unbiased advice on your fire protection problems, write to Grinnell Company, Inc., 274 West Exchange Street, Providence, Rhode Island.

Foam flows under aircraft to form a complete blanket.

Truck breasts hub-deep foam blanket outside hanger. Foam will dry out and disintegrate to a powder.

GRINNELL

WHENEVER FIRE PROTECTION IS INVOLVED

Manufacturing, Engineering, and Installation of Fire Protection Systems since 1870